DRAFT

INDOOR SMOKING FOLLOWING RELEASE OF THE EPA'S RISK ASSESSMENT

February 8, 1993

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INDEX

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2024689053

I. THE EPA'S RISK ASSESSMENT ON ETS IS NOT A REGULATION AND HAS NO DIRECT REGULATORY IMPACT OR EFFECT ON THE WORKPLACE.

On January 7, 1993, EPA Administrator William Reilly confirmed that the "EPA has no regulatory authority over environmental tobacco smoke."

The EPA's risk assessment on ETS clearly is at most an informational document; it absolutely is not a formal regulation.[1] The EPA does not have (and never has had) authority to regulate indoor air quality in general or ETS exposures in particular. Specifically, the EPA has no authority to regulate smoking in the workplace and has promulgated no regulations.

EPA maintains that it had statutory authority to develop the risk assessment under Title IV of the Radon Gas and Indoor Air Quality Research Act of 1986.[2] While even this authority is open to question, it is clear that Congress, when it enacted the Act, considered and rejected the possibility of giving EPA regulatory authority over indoor air. As passed, the Act specifically provides that it does not authorize the Administrator "to carry out any regulatory program or any activity other than research, development, and related reporting, information dissemination, and coordination activities specified in this title."[3]

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1. This is not to say, however, that others in the antismoking community are not trying to create a regulatory impact.

2. An Act, Oct. 17, 1986, P.L. 99-499, Title IV, §§ 401-405, 100 Stat. 1758, effective on enactment on Oct. 17, 1986.

3. Id. at § 404.

2024689055

II. OSHA HAS REGULATORY AUTHORITY OVER THE WORKPLACE AND WORKPLACE SMOKING. OSHA PRESENTLY HAS NO RULE OR REGULATION RESTRICTING SMOKING IN THE WORKPLACE.

The federal agency which currently has general regulatory authority over indoor air in the workplace is the Occupational Safety and Health Administration (OSHA), which is within the Department of Labor. In March 1992, OSHA closed the public comment period on a Request for Information (RFI) on indoor air quality,[1] in which the agency invited the general public to respond to 92 separate questions covering a full range of indoor air quality issues, including ventilation, operation and maintenance of HVAC systems, IAQ investigations, radon, bioaerosols, volatile organic compounds, ASHRAE standards, and IAQ costs. This overall inquiry specifically included ETS. OSHA has been reviewing the RFI comments to determine whether it is necessary and appropriate to regulate workplace exposures to substances in the indoor air environment.[2] Although OSHA may eventually propose a rule regulating indoor air quality and indoor smoking in the workplace, such a rulemaking has not yet been announced.[3]

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1. Federal Register, Vol. 56, No. 183, pp. 47892-97 (September 20, 1991).
2. 257 Science 607 (July 31, 1992).
3. See D.O.L. Press Statement, Secretary of Labor, January 14, 1993.

2024689056

III. OSHA IS NOT BOUND BY EPA'S CONCLUSIONS, PARTICULARLY WHEN EPA DID NOT ORIGINATE OR RELY UPON WORKPLACE DATA.

OSHA historically has not viewed itself as legally bound by EPA's conclusions. Nothing in OSHA's statutes or regulations refers directly to EPA's carcinogen classification scheme. A review of recent OSHA rulemaking provides no indication that an EPA conclusion of carcinogenicity, standing alone, has led in direct fashion to the initiation of any rulemaking by OSHA. Historically, an EPA determination of carcinogenicity is given no more weight than a similar determination by such organizations as the International Agency for Research on Cancer (IARC), the American Conference of Governmental Industrial Hygienists (ACGIH), or NIOSH, according to the review.

On January 14, 1993, then outgoing Secretary of Labor Lynn Martin directed OSHA, "as soon as possible consistent with applicable statutory requirements and executive orders, to commence rulemaking that addresses the occupational exposure" to ETS. However, Secretary Martin urges OSHA to consider all information, including the EPA's risk assessment. As to the latter, Secretary Martin emphasized that EPA focused upon the "home environment" and noted that OSHA would need "to examine these concerns and determine how they apply to the workplace."

2024689057

IV. **THE EPA'S RISK ASSESSMENT INVOLVED NO NEW RESEARCH BY EPA. THE RISK ASSESSMENT IS ANOTHER IN A SERIES OF LITERATURE REVIEWS AND, AS SUCH, CONTAINS NO NEW EPA RESEARCH AND DOES NOT CONTAIN FUNDAMENTALLY NEW SCIENTIFIC DATA OR CONCLUSIONS.**

Although some may argue to employers that the EPA's risk assessment is a dispositive statement on the health claims addressed in the document, it is but one in a series of interpretative review documents based on studies and conclusions already contained in the previously available published scientific literature regarding spousal smoking in the home. Stated another way, the risk assessment contains no new data, but rather provides EPA's interpretation of data that have already been reported in the published literature.

In content as well as in time, the EPA's risk assessment follows denouncements of ETS in other reports by the EPA itself,[1] by other government agencies in the United States[2] and other

1. See various EPA "Fact Sheets" on ETS; Building Air Quality (1991). The risk assessment was released in draft form in June 1990 and June 1992 with the same Group "A" classification. Note that Building Air Quality was published after the 1990 draft risk assessment but before the 1992 draft.

2. U.S. Department of Health and Human Services, "The Health Consequences of Involuntary Smoking: A Report of the Surgeon General" (1986); National Research Council, "Environmental Tobacco Smoke: Measuring Exposures and Assessing Health Effects" (1986). Note that National Institute for Occupational Safety and Health, "Current Intelligence Bulletin 54: Environmental Tobacco Smoke in the Workplace, Lung Cancer and Other Effects" (1991) was published after the original draft risk assessment but before the June 1992 revised draft.

In addition to the 1986 Surgeon General's report, which was (continued...)

2024689058

countries,[3] position papers by organizations and trade associations,[4] studies by scientists,[5] and United States judicial opinions

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2. (...continued)
exclusively devoted to ETS, nine Surgeon General's reports have contained a substantive discussion of health issues related to ETS. The most recent such report was issued in 1992; it asserted that laws that restrict smoking in the workplace "protect" employees from ETS and foster an environment in which smoking is deemed socially unacceptable. U.S. Department of Health and Human Services, "Smoking and Health in the Americas: A 1992 Report of the Surgeon General, in collaboration with the Pan American Health Organization" (1992). Note that this report was published after the 1990 draft risk assessment but before the 1992 draft. <u>See also</u> Memorandum regarding discussions of alleged ETS health risks in Surgeon General's Reports (A&P November 27, 1991).

3. <u>E.g.</u>, Froggatt Committee (United Kingdom); Australian National Health and Medical Research Council (1986); Canada Federal-Provincial Advisory Committee on Environmental and Occupational Health, "Exposure Guidelines for Residential and Indoor Air Quality" (April 1987). Note that WorkCover of New South Wales, "Passive Smoking in the Workplace: A Discussion Paper" (June 1991) and Dutch Health Council Report (1990) were published after the original draft risk assessment but before the June 1992 revised draft.

4. <u>E.g.</u>, World Health Organization, "IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Tobacco Smoking," Vol. 38, pp. 308, 314 (1986). Note that Association of British Insurers, "Smoking and the Work Place [sic]" (1991); National Heart Foundation of Australia, "Going Smoking-Free -- A Guide for Workplaces" (1991); U.S. National Electric Contractors Association, "Indoor Air Quality Problems and Solutions" (1991); American Industrial Hygiene Association, "Statement on Smoking in the Workplace" (1991) were published after the original draft risk assessment but before the June 1992 revised draft.

5. <u>See generally</u> Environmental Protection Association draft document, "Environmental Tobacco Smoke: A Compendium of Technical Information" (May 1991).

2024689059

in cases not involving tobacco companies in which courts have reached sometimes vague conclusions regarding ETS.[6]

Although the EPA's risk assessment on ETS is the first of these review documents to label ETS as a "Group A (known human) carcinogen," that label is unique to EPA and arguably does not reflect some heightened degree of alleged danger not reported previously. EPA's "Group A" designation is part of the agency's carcinogen classification scheme, which ostensibly refers to the amount and type of carcinogenicity data available on the substance being evaluated. A carcinogen designation made by EPA is not intended to denote the potency of a substance. Moreover, the classification scheme is not designed to confirm the extent of the hazard, if any, associated with a substance at levels typically

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6. See McCarthy v. Department of Social & Health Services, 110 Wash. 2d 812, 759 P.2d 351, 355 (1988) ("[t]he hazardous nature of cigarette smoke to nonsmokers is well established"); Shimp v. New Jersey Bell Tel. Co., 145 N.J. Super. 516, 368 A.2d 408 (1976) ("The evidence is clear and overwhelming. Cigarette smoke contaminates and pollutes the air, creating a health hazard not merely to the smoker but to all those around her who must rely upon the same air supply.").

Australian Federation of Consumer Organizations Inc. v. The Tobacco Institute of Australia Limited, ATPR ¶ 41-079 (Federal Court of Australia February 7, 1991) (Morling, J.) was issued after the original draft Risk Assessment but before the June 1992 revised draft. The Tobacco Institute of Australia appealed Justice Morling's opinion; the appeal was argued in February 1992 and a decision could be reversing Justice Morling's injunction against the Tobacco Institute of Australia was issued in early 1993.

2024689060

encountered.[7]

7. Environmental Protection Agency, Guidelines for Carcinogen Risk Assessment, Federal Register, Vol. 51, No. 185, pp. 33992-34003 (1986).

V. THE EPA'S RISK ASSESSMENT IS NOT BASED UPON AN ANALYSIS OF WORKPLACE EXPOSURES AND PROVIDES NO NEW RESEARCH OR DATA CONCERNING WORKPLACE EXPOSURES. THE CLAIM THAT EXPOSURE TO TOBACCO SMOKE AT WORK INCREASES THE NONSMOKER'S RISK OF DISEASE IS NOT JUSTIFIED BY THE SCIENCE.

The EPA's risk assessment involved a review of already existing literature concerning ETS exposures in the "home environment." The EPA conducted no research, conducted no testing and in fact did no field work whatsoever involving the workplace. Indeed, even if EPA had reviewed the literature which addresses workplace exposures and had tried to draw conclusions from that data, such a review does not support the conclusion that exposure to ETS in the workplace causes lung cancer.

Measurements taken in offices, workplaces and public places indicate that the contribution of tobacco smoke to the air we breathe is minimal. For example, typical nicotine measurements (which are particularly revealing because nicotine is unique to tobacco smoke) range from an exposure equivalent of 1/100 to 1/1000 of one filter cigarette per hour. In other words, a nonsmoker would have to spend from 100 to 1000 hours in an office, restaurant or public place in order to be exposed to the nicotine equivalent of just one cigarette.

Other researchers who have measured tobacco smoke constituents in offices indicate that simple separation of smokers and nonsmokers effectively minimizes such exposures. One recent study reported that the use of designated smoking areas reduced exposure to ETS by 95%. Another study of a smoking-restricted

2024689062

office building reported that ambient nicotine in nonsmoking areas was virtually undetectable, suggesting that ETS had a negligible impact on the nonsmoking areas of the building.

Fourteen of the 33 available epidemiologic studies on spousal smoking and lung cancer in nonsmokers have included data on the possible relationship between ETS exposures in the workplace and the development of lung cancer in nonsmokers. Only two of the 14 studies report statistically significant associations between reported workplace exposure and an increased risk of disease in nonsmokers. Data from 12 studies are consistent with the claim that there is no association between ETS exposure in the workplace and an increased risk of lung cancer among nonsmokers.

A 1980 report which concluded that nonsmokers exposed to tobacco smoke at work for 20 or more years had reduced function of the small airways compared to nonsmokers not so exposed still receives considerable attention, although it was heavily criticized for questionable data acquisition and analysis. In contrast, a more recent study of 1,351 German office workers reportedly found "no evidence" that everyday exposure to tobacco smoke in the office or at home leads to an essential reduction of lung function in healthy adults.

One of the most widespread beliefs, especially in the workplace setting, is that some nonsmokers are "allergic" to tobacco smoke. Scientific researchers, however, have <u>not</u> identified specific allergens in tobacco smoke. Thus, while some individuals

2024689063

may react to the sight or smell of tobacco smoke, this does not mean that they are experiencing an "allergic" reaction to it.

VI. THE DECISION BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY TO CLASSIFY ENVIRONMENTAL TOBACCO SMOKE AS A GROUP "A" CARCINOGEN IS NOT JUSTIFIED BY THE AVAILABLE SCIENCE.

An objective review of the available studies -- including one of the newest and largest studies, which was not considered by the EPA -- leads to a conclusion that the scientific data do not convincingly support a conclusion of an increased risk of lung cancer to nonsmokers from ETS. Consider, for example:

- Twenty-four of the 30 lung cancer studies reviewed by the EPA do not support the agency's conclusion; those 24 reported no statistically significant overall association between ETS and lung cancer.
- The EPA relied on 11 studies conducted in the United States to estimate the relative risk associated with ETS, not one of which originally achieved overall statistical significance for a risk estimate. Only after the EPA went back and lowered the original statistical standards used by the individual studies' authors was the EPA able to force a conclusion of increased risk. The lowering of the statistical standards used by the studies' authors is unprecedented and appears to be the only way the EPA could reach its conclusion of increased risk.
- The EPA did not include one of the largest and most recent studies on ETS, which was funded in part by the National Cancer Institute. This study reported

no overall statistically significant association between ETS and lung cancer. Had the study data been included in the ETS risk assessment and analyzed using accepted statistical standards, the overall lung cancer risk estimate from ETS exposure would not have been statistically significant.

- The EPA calculated a risk estimate of 1.19 for ETS. On a scale where 1.0 indicates no increased risk, 1.19 indicates a very weak association. Epidemiologists generally agree that a relative risk of less than 2.0 is considered "weak."
- Dr. Morton Lippmann, chairman of the Science Advisory Board committee that reviewed the risk assessment, has acknowledged the extremely weak association on more than one occasion:

(i) Speaking to reporters in April 1991, he said the provided risk of ETS was "probably much less than you took to get here through Washington traffic" to attend the news conference held to discuss the committee's recommendations on the first draft of the risk assessment.

(ii) In October 1992, commenting on the second draft of the risk assessment, Lippmann stated that, "Admittedly, the epidemiological (support) is not as clearly convincing as one would hope."

- This is the first time EPA has recommended a Group "A" classification for a substance based on weak epidemiologic data, and with no corroborating animal data. The few existing animal ETS exposure studies do not support the EPA's conclusions.

Simply stated, the scientific data relied upon by the EPA do not convincingly support the EPA's conclusion that ETS poses a significant risk to nonsmokers in the workplace.

VII. 24 OF THE 30 STUDIES REVIEWED BY THE EPA, AND ON WHICH IT BASED ITS RISK ASSESSMENT CALCULATIONS, REPORTED NO STATISTICALLY SIGNIFICANT INCREASED RISK.

The concept of "statistical significance" is important because it permits a scientist to infer either that the data in a study support or do not support a given hypothesis.

As stated previously, the data in 24 of 30 epidemiological studies on spousal smoking and lung cancer relied upon by the EPA are compatible with the hypothesis that there is no overall association between spousal smoking and lung cancer. Typically, when results do not achieve statistical significance, further analysis of the data is not meaningful or productive. Apparently, the EPA does not ascribe to this accepted statistical principle. While data from the six remaining statistically significant studies permit the scientist to reject the hypothesis of no association, the scientist must further investigate whether the statistically significant association is due to the exposure in question or to some other risk factor.

VIII. OF THE U.S. STUDIES REVIEWED BY THE EPA, NOT ONE ORIGINALLY REPORTED AN OVERALL STATISTICALLY SIGNIFICANT RISK.

The EPA reviewed 30 studies involving reported spousal exposure to ETS in the "home environment." Of those studies, eleven were U.S. studies. It should be emphasized that none of the eleven U.S. studies reviewed by EPA reported an overall statistically significant risk estimate. Moreover, even when the EPA recalculated the statistical confidence limits for the 11 U.S. studies, only one of those studies reportedly achieved statistical significance.

2024689069

IX. OF THE STUDIES THE EPA CONSIDERED, 11 INCLUDED ESTIMATES OF WORKPLACE EXPOSURES, OF WHICH TEN REPORTED NO STATISTICALLY SIGNIFICANT INCREASED RISK FOR NONSMOKING FEMALES.

As Secretary of Labor Lynn Martin emphasized on January 14, 1993, the EPA's risk assessment focuses primarily upon spousal exposure to ETS in the "home environment." However, even from the "home environment" studies, if the data on workplace exposures are pooled in a meta-analysis, the risk estimate is below 1.00 (unity), which indicates no positive association between reported workplace exposures to ETS and lung cancer in nonsmokers. Significantly, the EPA's risk assessment did not rely upon those data in reaching risk assessment conclusions.

2024689070

X. THE EPA OMITTED FROM ITS ETS RISK CALCULATION DATA FROM THE NCI-FUNDED BROWNSON STUDY, ONE OF THE LARGEST AND MOST RECENT STUDIES ON ETS AND LUNG CANCER, WHICH REPORTED NO OVERALL INCREASE IN RISK FROM EXPOSURE TO ETS. IF THE EPA HAD INCLUDED THE BROWNSON STUDY, ITS RISK ASSESSMENT WOULD NOT HAVE FOUND A STATISTICALLY SIGNIFICANT INCREASED RISK OF LUNG CANCER DUE TO EXPOSURE TO ETS.

The EPA's risk assessment did not even include all then available U.S. data.

The EPA did not include the data from the Brownson study in its calculations. See Brownson, R.C., Alavanja, M.C.R., Hock, E.T., and Loy, T.S. "Passive Smoking and Lung Cancer in Nonsmoking Women," American Journal of Public Health 82: 1525-1530, 1992. This case-control study is among the largest conducted on reported ETS exposure and lung cancer incidence. It includes 432 "lifetime" nonsmokers and 186 exsmokers, and 1,402 controls. An odds ratio of 1.0 (95% CI 0.8-1.2) was reported for spousal smoking in nonsmokers (218 cases and 598 controls). This odds ratio is not statistically significant.

If the Brownson study is added to EPA's meta-analysis of the U.S. ETS-lung cancer studies, and if the EPA's method of adjustment for misclassification is applied to the study, the resulting summary risk estimate for all U.S. studies does not exceed 1.07, a risk estimate which is not statistically significant at a 95% confidence interval.

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XI. THE EPA WOULD NOT HAVE CLASSIFIED ETS AS A GROUP "A" CARCINOGEN HAD THE EPA USED THE METHODOLOGIES AND GUIDELINES IT EMPLOYED IN PREVIOUS RISK ASSESSMENTS.

With the ETS risk assessment, the EPA has established a precedent-shattering framework for other future risk assessments. As proclaimed by Dr. William Farland, from EPA's Office of Health and Environmental Assessment to the Science Advisory Board's IAQTHEC meeting on July 21, 1992:

> This (the ETS risk assessment) is a high visibility assessment . . . because of its implications for the future of the way we do business. (Meeting transcript, at I-31).
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> First of all, we have a focus on human data which is fairly unique in terms of dealing with environmental pollutants. (Meeting transcript, at I-33).
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> Another fairly unique situation with regard to environmental risk assessments is we've taken the opportunity to use some new techniques, meta-analysis for lung cancer, that we think will be important to us in terms of combining information from various studies as we do risk assessments in the future. (Meeting transcript, at I-34.)
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> So, we think that there are some interesting and important features and <u>an opportunity to do some innovative risk assessment work in this particular assessment</u>. (Emphasis added.) (Meeting transcript, at I-35.)
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> So these are all features of this particular assessment that we think are going to have a

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> great impact on the way we do future assessments in the Agency. . . . (Meeting transcript, at I-36.)

If the EPA had followed its own 1986 draft Carcinogen Risk Assessment Guidelines, it would have included: (1) a hazard evaluation, which would have examined data regarding the physical and chemical characterization of ETS, as well as the results from published animal inhalation studies and in vitro studies; (2) an exposure evaluation, which would have included the data from well over 100 studies in the published literature which monitored ETS constituents in the air of public places and work places; (3) a dose-response evaluation, which would have included an examination of the actual data reported in the epidemiologic studies on spousal smoking; and (4) a risk characterization, which would have included the range of uncertainty in numbers of lung cancer deaths reportedly attributed to ETS exposures. The guidelines also require, for the evaluation of epidemiologic studies, that chance must be ruled out statistically (i.e., the results should be statistically significant), and that all possible biases and possible confounding factors in such studies are to be considered. The EPA's current strategy to classify ETS as a Group A carcinogen based solely upon epidemiologic studies would have failed had they carefully adhered to their own guidelines.

XII. TO PLACE MATTERS IN PERSPECTIVE, IF THE EPA SUBJECTS CHLORINATED DRINKING WATER, THE ORDINARY TAP WATER CONSUMED BY MOST AMERICANS, TO THE EXACT SAME METHODOLOGY IT APPLIED TO ETS, CHLORINATED WATER WOULD ALSO BE A GROUP A CARCINOGEN.

If EPA consistently applies it own scientific methodologies, the data currently available to EPA suggest that exposure to chlorinated drinking water is associated with health risks that are greater than those alleged by EPA to be associated with ETS.

According to the results of a meta-analysis on the chlorination of water and chlorination by-products, published in the American Journal of Public Health (July 1992), the authors reported that "a sample meta-analysis of all cancer sites yielded a relative risk estimate for exposure to chlorination by-products of 1.15." These results were statistically significant, as were results reported for "organ-specific neoplasms" such as bladder cancer and rectal cancer. The meta-analysis was based upon the adjusted relative risk estimates from epidemiologic studies, precisely the same basis used in the EPA risk assessment on ETS. The estimated results were reportedly statistically significant, even after the apparent adjustment for confounding factors.

In a November 1992 EPA workshop related to health risks of chlorinated drinking water, Dr. Devra Davis of the National Academy of Sciences confirmed that the reported drinking water health effects are greater than those alleged by the EPA for ETS:

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Dr. Crown, you said there was little evidence for the effects of chlorinated water on health. Let me disagree specifically in the following ways. I think there is evidence on cancer, I think that there is a general consensus now about the fact that there is such evidence. Let me remind you that the relative risk we are talking about here is higher than the relative risk for environmental tobacco smoke. The difference is that no one likes environmental smoke. Its easy for people to say 'oh, let's get rid of that smoke, it's nasty and horrible,' but in fact the relative risk we are talking about there in the highest exposed group in cancer study was higher than the relative risk, for the average, in lung cancer for someone who married a smoker. Think about that.

Despite data which suggest that there are greater health risks associated with exposure to chlorinated drinking water than the risks alleged by EPA to be associated with spousal exposure to ETS, the EPA has taken no action on chlorinated drinking water comparable to the ETS risk assessment.

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XIII. THE NATIONAL CANCER INSTITUTE HAS COMPLETED A MAJOR STUDY WHICH REPORTS THAT POOR DIET AMONG NON-SMOKING WOMEN IS A SIGNIFICANT RISK FACTOR FOR LUNG CANCER. IF THAT IS CORRECT, IT SUGGESTS THAT ALL ETS STUDIES REVIEWED BY THE EPA AS A PART OF THE ETS RISK ASSESSMENT THAT DID NOT TAKE DIET INTO CONSIDERATION, SHOULD BE RE-EVALUATED.

Many factors, including diet, may be risk factors for lung cancer. Other risk factors for lung cancer include personal medical history, certain occupational exposures, family history of cancer, and use of certain fuels for heating and cooking. The EPA did not adequately take into account factors such as diet in its risk assessment analyses.

A recent report by the National Cancer Institute (NCI) that poor diet among nonsmoking women is a significant risk factor for lung cancer should have compelled action by the EPA. Several of the published studies on spousal smoking considered by the EPA have adjusted for the importance of diet. While the results are mixed, several suggest that a healthy diet, or, conversely, the avoidance of a poor diet containing fat and spicy foods, will affect reported risk estimates for nonsmokers married to smokers. Other studies suggest that diet is an independent risk factor for lung cancer.

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XIV. THE COMMON LAW RIGHT TO A SAFE WORKING ENVIRONMENT HISTORICALLY PROVIDES LITTLE SUPPORT FOR WORKPLACE SMOKING BANS. THE EPA'S RISK ASSESSMENT DOES NOT PROVIDE ANY NEW RESEARCH DATA WHICH ALTERS OR MODIFIES THE SCIENCE UNDERLYING THIS LEGAL ANALYSIS.

The current legal landscape is that courts have been reluctant to intervene in disputes regarding smoking in the workplace and, with a few notable exceptions, have refused to find a right to work in a smoke-free environment. In determining the extent to which smoking in the workplace may be restricted, courts generally have recognized the need to consider the interests and rights of both smoking and nonsmoking employees.

A. Proof of Causation Relating to Any Alleged Indoor Air Exposure is Difficult to Establish

A key element in any potential claim for personal injury by an employee against an employer is causation, i.e., whether a plaintiff can prove that it is more likely than not that an exposure to some aspect of the indoor environment caused the injury that plaintiff alleges. A potential plaintiff will experience the same problems of proof with a claim of injury due to an alleged ETS exposure as he or she would with any other workplace exposure claim.

To date, in cases involving workplace exposures to ETS, some courts have found a causal relationship between ETS and respiratory diseases, but usually only if the plaintiff is allegedly

"hypersensitive."[1] Even in those cases, there are indications that the causation issue has not been vigorously contested.

If a future plaintiff succeeded in proving general causation, even after the EPA's risk assessment, he or she still would have to prove specific causation, satisfy the requirements of proximate cause, and prove all other elements of each cause of action asserted. In the context of alternative causation and alternative exposures in the contemporary nonindustrial workplace, the difficulty of plaintiff's task cannot be understated. The EPA's risk assessment on ETS does nothing to alter these very significant practical problems of proof. The complexities of accurately assessing low level exposure and the resultant dose of any alleged indoor air exposure are not addressed, much less resolved by the EPA's risk assessment.

B. It Has Not Been Established that An Employer's Duty to Provide A Safe Workplace Means No Smoking

Some may allege that an employer's failure to provide a smoke-free workplace breaches the common-law duty to provide a reasonably safe workplace. However, such claims are not supported by existing case law.

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1. See, e.g., County of Fresno v. Fair Employment and Housing Commission of the State of California, 277 Cal. Rptr. 557, 562-63 (Cal. App. 1991), review denied (April 11, 1991) (handicap discrimination); Johannesen v. New York City Department of Housing Preservation and Employment, 154 A.D.2d 753, 546 N.Y.S.2d 40, 41 (1989) (workers' compensation); Alexander v. Cal. Unemployment Insurance Appeals Board, 104 Cal. App. 3d 97, 163 Cal. Rptr. 411, 412 (1980) (unemployment compensation).

2024689078

Under limited, narrowly-defined circumstances, three courts in the United States have allowed an employee claiming physical injury from ETS exposure to pursue a cause of action against his or her employer for failure to provide a smoke-free workplace.[2] In only one of those cases, however, Shimp v. New Jersey Bell Tel. Co.,[3] decided in 1976, did the court actually award relief to the plaintiff -- an injunction prohibiting the employer from allowing smoking in its work areas.

In Shimp, a secretary who claimed a severe allergic reaction to ETS sought to have smoking banned in the area where she worked. New Jersey Bell, the defendant in the case, elected not to serve an answer or other response. Confronted with plaintiff's uncontested claim, the presiding judge directed New Jersey Bell "to provide safe working conditions for plaintiff by restricting the smoking of employees to the nonwork area presently used as a lunchroom." 368 A.2d at 416.

Contrary to the "avalanche-of-litigation" impression antismoking advocates have sought to create, the Shimp decision has not been followed in the 17 years since it was handed down. In fact, in response to an identical complaint filed shortly

2. See McCarthy v. Department of Social and Health Services, 110 Wash. 2d 812, 759 P.2d 351 (1988); Shimp v. New Jersey Bell Tel. Co., 145 N.J. Super. 516, 368 A.2d 408 (1976); Smith v. Western Electric Co., 643 S.W.2d 10 (Mo. Ct. App. 1982), on remand, Smith v. AT&T Technologies, No. 4446121 (Cir. Ct., St. Louis County, Missouri, unpublished, April 23, 1985). See generally citations at footnote 24, supra.

3. Shimp, 368 A.2d at 415-16.

thereafter by the same attorney on behalf of another New Jersey Bell employee, New Jersey Bell elected to defend itself and promptly prevailed. A motion to dismiss the case was filed by the company, and the case was dismissed by the same trial judge who heard the Shimp case. Mitchell v. New Jersey Bell Telephone Co., No. C-4159-76 (N.J. Super. Ct. Ch. Div.).

As summarized by one commentator, a variety of factors limit any precedential value of the Shimp decision:

> One can perceive, then, that Shimp is made up of many important facts, the absence of any of which could persuade a court to find differently. Further, this is not the Supreme Court in New Jersey, nor has the decision been followed by any other courts in New Jersey or elsewhere.
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> Finally, the court's use of an injunction in this area is unprecedented. Injunctions like the one in Shimp are relatively scarce; the courts look for irreparable injury, clear rights, and absolutely no other remedies. Blackburn, Legal Aspects of Smoking in the Workplace, 31 Labor L.J. 564, 568 (1980) (footnote omitted).

Perhaps the most telling refutation of the Shimp case is found in another subsequent case decided by a New Jersey state court of equal status. Smith v. Blue Cross & Blue Shield of New Jersey, No. C-3617-81E (N.J. Super. Ct. Ch. Div. 1983). There, as in Shimp, an employee alleged hypersensitivity to cigarette smoke and sought, among other things, to force her employer to promulgate and enforce a variety of smoking restrictions. In denying relief, the court addressed Shimp in the following terms:

> Insofar as the Shimp case is read by some as requiring an employer to institute Draconian measures to smoking employees, I think it has to be viewed somewhat skeptically and cautiously. I myself have no problem at all with the basic concept of Shimp, that a safe workplace is required, but I must say it seems to me that some of the prohibitions contained in the Shimp case are too sweeping and go well beyond what is necessary to ensure a safe working place. Transcript of Trial Proceedings of August 18, 1983, at 8.

More generally, the court rejected the claim that employers have an obligation to accede to the demands for sweeping smoking restrictions. The court defined the relevant duty of care in the following terms:

> What the employer must do is accommodate the needs of the typical employee who is a typical nonsmoking employee and that person must be given not only a healthy environment but one which is reasonably pleasant in the fullest sense, and that sort of a person must be protected from offensive smoking habits, but what we are being asked to do here goes well beyond that. It's well beyond supplying a safe workplace, goes well beyond supplying a reasonably pleasant workplace, goes well beyond accommodating a problem or handicap. What we are really being asked for here is to impose upon every employee * * * who wishes to smoke a regime, a form of discipline which goes well beyond the reasonable, all under the guise of catering to the very particularized needs of a supersensitive person. That is not appropriate. Id. at 16-17.

Some undoubtedly will try to argue that the EPA's risk assessment, by itself or in addition to other studies and reports, demonstrates that it is more probable than not that any workplace in which smoking is allowed is unreasonably unsafe, and that the employer should be enjoined from permitting smoking on the premises

and/or made to pay damages for injuries allegedly caused by exposure to smoking on the premises. However, a current, objective interpretation of the scientific literature addressing health issues related to ETS, coupled with data from various organizations (including NIOSH) about the relative roles of ventilation and ETS in the indoor air environment, indicate -- in our opinion -- (i) that the EPA's decision to classify ETS as a Group A carcinogen is not justified by the available science, (ii) that, in any case, the EPA did not research, rely upon or investigate possible workplace exposures to ETS, and (iii) that existing workplace data indicates that simple separation of smokers and nonsmokers effectively minimizes nonsmoker exposure to ETS in the workplace. There is no data in the EPA report or in the published literature which convincingly establish that these workplace exposures cause lung cancer.

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XV. IN A NUMBER OF INSTANCES, EMPLOYERS IN ETS CASES WHO HAVE CONTESTED CAUSATION AND ARGUED ALTERNATIVE EXPOSURES HAVE BEEN SUCCESSFUL.

Even after the EPA's risk assessment, if a future plaintiff succeeded in proving general causation, he or she still would have to prove specific causation, satisfy the requirements of proximate cause, and prove all other elements of each cause of action asserted. Those employers who have argued alternative causation and alternative exposures have been successful in a number of different circumstances.

For example, in a recent case filed by an office worker who claimed that she was handicapped by an "abnormal allergy" to tobacco smoke, her employer developed the following facts: (i) that the worker had complained to a variety of substances at other work locations where she had been assigned by her employer, including fumes from an oil fired furnace, fumes from an unknown source, fumes from motor vehicles, and odors from new furnishings; (ii) that the worker was a former smoker who showed no physical sensitivity to tobacco smoke when she worked; (iii) and that she had once written a letter to a state agency in which she claimed that her intolerance to ETS and a wide variety of other substances (including cosmetics, paint, cleansers and building maintenance products) prevented her from continuing to work for the employer. The employer also presented evidence that the office building to which the worker was assigned when she filed her handicap discrimination complaint was well-ventilated and that an indoor

air quality test indicated no concentration of ETS or gas in the building.

Based on this evidence, the trial court entered judgment for defendants. See Gupton v. Commonwealth of Virginia, No. 3:91CV00358 (D. Va. 3/6/92) (appeal pending in 4th Cir.). The court found that the worker was not handicapped, and that even if she had been, her employer had reasonably accommodated her by assigning her to a no-smoking area. The court specifically noted that Ms. Gupton had never been tested for allergies to ETS; that there is no medically-accepted test for any such allergy; and that the ventilation in the worker's building was adequate, "furnishing sufficient air exchange to prevent any appreciable buildup of substances found in environmental tobacco smoke."

Similarly, in another 1992 case, the Supreme Court of Nevada rejected an ETS workers' compensation claim filed by a casino worker, stating that, as a matter of law, "secondary smoke is a hazard to which workers, as a class, may be equally exposed outside of the employment." Palmer v. Del Webb's High Sierra, _____ P.2d _____, 1992 WL 211632 (Nev. 9/1/92) (single quotation marks omitted). As in Gupton, the court's decision acknowledged the importance of ventilation in a workplace environment.

> It is probably true that more environmental smoke is associated with the casino and bar businesses; still, the amount and density of such tobacco smoke is highly inconstant and may range from none to quite dense, depending on the particular bar or casino and depending on the air filtration systems and other variables that vary from business to business.

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Palmer is consistent with an earlier case decided in Oregon, _Matter of Compensation of Thompson_, 51 Or. App. 395, 625 P.2d 1348 (1981). In that case the court held that a plaintiff who alleged that she was allergic to a variety of "common substances," including tobacco smoke, had not suffered an "occupational disease" required for workers' compensation benefits. In the sixth year of her employment, Ms. Thompson "began to experience a progressive onset of symptoms, including headaches, dizzy spells, nausea, nose bleeds and skin rashes." 625 P.2d at 1349. She indicated that her symptoms were precipitated "by many common substances, including tobacco smoke, hair spray, perfumes, paints and strong odors." _Id._

It was clear to the Thompson court that plaintiff's exposure was not limited to substances in the work environment. _Id._ at 1351. In Oregon, the court said, a condition is compensable as an occupational disease only if it was caused by circumstances to which an employee is not ordinarily subjected or exposed other than during a period of regular employment. Other state's statutes use similar language. Thompson concluded, therefore, that Ms. Thompson had not established that she had an occupational disease and could not recover under workers' compensation. _Id._

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XVI. EMPLOYERS, BUILDING OWNERS AND BUILDING MANAGERS SHOULD ADDRESS AND EVALUATE INDOOR AIR QUALITY AND TOTAL INDOOR ENVIRONMENTAL QUALITY. IN THAT CONTEXT, DECISIONS SHOULD BE MADE ON INDOOR SMOKING WHICH ARE BEST SUITED TO THE PARTICULAR INDOOR ENVIRONMENT AND WHICH OTHERWISE COMPLY WITH APPLICABLE LOCAL LAWS.

A total building systems approach to achieving and maintaining acceptable indoor environmental quality and adequate indoor air quality emphasizes attention to the proper design, operation and maintenance of a building's indoor systems including the heating, ventilation and air-conditioning (HVAC) system, lighting, noise and overall workplace design.

One important factor in the building systems approach is ventilation, which, in turn, includes provisions for adequate outdoor supply air and its distribution to occupied spaces. The objective is to decrease exposure to substances in the indoor air and to prevent and/or alleviate complaints about indoor air quality. A complete program for a building systems approach would also include provisions for the appropriate design and construction of HVAC systems, criteria for operation, scheduled inspections and maintenance of HVAC systems, and a statement of performance criteria, all required in order to ensure performance of the HVAC system to specifications. This is a performance-orientated, "engineering systems" approach which requires the inter-disciplinary expertise of architects, mechanical engineers, HVAC contractors and maintenance engineers.

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The approach recognizes the existence of potential "significant risk" and/or "material impairment" from worker exposures to poor indoor environmental quality, as documented by literally thousands of building investigations completed in the past decade. It acknowledges that individual causes of complaints related to indoor air quality in "problem buildings" are rarely identifiable, and that suspected causes of poor indoor air quality are likely to be multi-factorial, involving any number of substances at low exposure levels, as well as comfort-related factors such as air movement, temperature, lighting and humidity.

The approach offers a comprehensive solution to poor indoor air quality. Adequate supply air intake and its distribution serve to dilute and/or remove a wide range of substances potentially in the indoor air, including volatile organic compounds such as benzene and formaldehyde (VOCs), carbon monoxide (CO), carbon dioxide (CO_2), constituents of environmental tobacco smoke (ETS), radon, biologicals, etc. Maintenance (inspection and cleaning) of HVAC systems is particularly important in the case of biologicals. That is why the building systems approach emphasizes proper design, operation and maintenance of HVAC systems. This solution remains constant as the work activities of building tenants and the "mix" of substances in indoor air change over time. The effectiveness of the building systems approach is supported by data in the published literature.

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The buildings systems approach is also a feasible solution to indoor environmental quality problems and to the maintenance of acceptable indoor air. The approach relies upon existing technology and standards for the design, operation and maintenance of systems. It is likewise a cost-effective solution, because any costs associated with implementation of the approach are likely to be small, and offset by a reduction in complaints and a potential increase in worker productivity. The approach directs resources to controlling the widest range of potential substances in indoor air.

Because it is visible and easily identified by its aroma, ETS is often initially identified as the probable cause of indoor air quality complaints. However, data on actual workplace exposure levels to ETS constituents, together with conclusions derived from eight major databases on sick-building syndrome, indicate that tobacco smoke is rarely the underlying cause of complaints about poor indoor air quality.

For example, in Healthy Building International's database of 412 sick-buildings, ETS was reported to be a significant contributor to complaints in only 3 percent of all buildings investigated.

In the "sick building" database compiled by TDSA Ltd., smoking was implicated as a major contributor to complaints in only 12 of 408 (less than 3 percent) of the buildings surveyed.

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National Institute of Occupational Safety and Health (NIOSH) investigated more than 200 "sick buildings" through 1984 and reported that tobacco smoke was a source of claimed discomfort in only 2 percent of the buildings investigated.

In a summary of 94 building studies by government investigators from Health and Welfare Canada, complaints were attributable to indoor constituents such as photocopy machine emissions and ETS in only 5 percent of the buildings investigated. In all of the databases, inadequate ventilation was determined as the underlying source of complaints in over half of all investigations.

It is nevertheless understandable, given the easy recognition of ETS, that persons experiencing sick-building symptoms initially tend to blame ETS. Indeed, researchers have indicated that the mere visibility or presence of tobacco smoke may provoke claims that ETS is the cause of reported symptoms and complaints. This is likely to be especially true when an individual is already feeling discomfort in a sick building setting. However, as one commentator has pointed out: "Removing the smoker entirely . . . would not effect health and comfort problems in 95 to 98 percent of sick-buildings."

Moreover, published data submitted on the contribution of ETS constituents to overall ambient air levels in typical workplaces suggest that such contributions are minimal and often indistinguishable from contributions from other sources. Of course,

2024689089

data from monitoring studies on ETS-related constituents in the workplace are varied and depend on a number of factors, such as the number of smokers present, activity levels, ventilation, total volume, etc. Nevertheless, it is possible to observe trends in the data. For example, after a review of 37 supporting studies from the published literature, Philip Morris reports that:

> . . . [T]here is little difference in ambient levels of carbon monoxide in smoking and nonsmoking areas of workplaces and public places and in homes with and without smokers. Other studies indicate that PTS contributes approximately 30 percent of the total particles in the air of a typical public place. Nicotine is often used as marker for PTS exposures because it is unique to tobacco smoke. Typical measurements of nicotine range from an exposure equivalent of 1/100 to less than 1/1,000 of one filter cigarette per hour. This means that a nonsmoker would have to spend from 100 to 1,000 hours or more in an office, restaurant, or public in order to be exposed to the nicotine equivalent of a single cigarette.

Philip Morris also observes that "studies which have examined ETS constituent levels of nitrosamines, nitrogen oxides and volatile organic compounds (such as benzene) report minimal contributions to overall ambient air levels in homes, the workplace, and public places."

Thus, a review of the scientific data on exposure levels to ETS in the workplace, together with analyses of those studies, indicate that typical workplace levels of ETS constituents are not associated with a significant risk to nonsmoking workers.

Further, the available published epidemiologic data on reported ETS exposures in the workplace and various chronic disease

endpoints in nonsmokers do not support the claim that ETS poses a significant risk for chronic disease among workers. This is not to deny that some individuals may nevertheless report annoyance or irritation by the sight or smell of ETS. The building systems approach to achieving and maintaining adequate indoor environmental quality is designed to address those kinds of complaints.

2024689091

XVII. <u>THE RIGHTS OF SMOKERS COVERED BY COLLECTIVE BARGAINING AGREEMENTS MUST BE CONSIDERED BEFORE SMOKING RESTRICTIONS ARE IMPOSED IN THE WORKPLACE.</u>

A number of decisions have held that an employer may not unilaterally impose smoking restrictions or bans in the workplace when a collective bargaining agreement is in effect. The consistent holding has been that workplace smoking restrictions or bans affect conditions of employment that are within the scope of the collective bargaining process.

In <u>Commonwealth of Pennsylvania v. Pennsylvania Labor Relations Board</u>, 459 A.2d 452 (Pa. Commw. Ct. 1983), for example, the court held that because imposition of a change in smoking policy affects conditions of employment, an employer cannot impose smoking restrictions outside the collective bargaining process. As stated by the court:

> The subject of whether employees may smoke at their workplace appears to be at the center of those subjects properly described as 'conditions of employment' and to be entirely unrelated to those entrepreneurial or managerial judgments fundamental to the basic direction of the enterprise and removed from the scope of mandatory bargaining. *** <u>Id.</u> at 455.

In Johns-Manville Sales Corp v. International Ass'n of Machinists, Local Lodge 1609, 621 F.2d 756 (5th Cir. 1980), the United States Court of Appeals for the Fifth Circuit likewise upheld an arbitrator's decision invalidating Johns-Manville's smoking policy under the terms of the company's collective bargaining agreement. The court affirmed the arbitrator's ruling that the

company could not discharge an employee for refusing to stop smoking and stated that governmental agencies, and not the courts, are the "appropriate forum for the formulation of industrial sumptuary or health-protection codes." Id. at 760

More recently, in Department of Health and Human Services v. Federal Labor Relations Authority, 920 F.2d 45 (D.C. Cir. 1990), the Court of Appeals for the District of Columbia Circuit affirmed these same principles. The court struck down a smoking ban unilaterally imposed by the Department of Health and Human Services on its own office facilities, noting that the Federal Labor Relations Authority has "consistently rejected . . . agency arguments advanced to justify refusing to bargain over the scope of smoking bans." Id. at 49, citing National Ass'n of Gov't Employees, and Dep't of the Army, Fort Leonard Wood, Missouri, 26 F.L.R.A. 593 (1987), and Indian Health Service v. FLRA, 885 F.2d 911 (D.C. Cir. 1989).

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XVIII. THE COURTS HAVE REJECTED THE CONTENTION THAT THE UNITED STATES CONSTITUTION GIVES NONSMOKERS THE RIGHT TO COMPEL EMPLOYERS TO PROHIBIT SMOKING IN THE WORKPLACE.

Smoking in the workplace is not, of course, anything new. By contrast, the legal theories that have been advanced to force severe restrictions or bans on workplace smoking have often been somewhat novel. These include the notion that the United States Constitution can be invoked to ban smoking.

The leading case is Gasper v. Louisiana Stadium and Exposition District, 418 F. Supp. 716 (E.D. La. 1976), aff'd, 577 F.2d 897 (5th Cir. 1978), cert. denied, 439 U.S. 1073 (1979). In Gasper, a group of nonsmokers sued to compel the management of the Louisiana Superdome to prohibit smoking during sporting and other events. In support of their demand, plaintiffs claimed a constitutional right to a "smoke-free" environment, relying upon the First Amendment's guarantee of free speech, and the due process protection afforded by the Ninth Amendment, which protects unspecified rights regarded by the courts to be of a "fundamental" nature.

The District Court in Gasper unequivocally rejected any constitutional basis for restricting smoking. Responding to the First Amendment claim, the court held that "the State's permissive attitude toward smoking in the Louisiana Superdome adequately preserves the delicate balance of individual rights without yielding to the temptation to intervene in purely private affairs." 418 F.

Supp. at 718. In rejecting the due process claims, the court concluded that to apply the Fifth and Fourteenth Amendments to prohibit smoking --

> would be creating a legal avenue, heretofore unavailable, through which an individual could attempt to regulate the social habits of his neighbor. This Court is not prepared to accept the proposition that life-tenured members of the federal judiciary should engage in such basic adjustments of individual behavior and liberties. Id. at 721.

Finally, the court rejected the "fundamental right" theory advanced by the plaintiffs, holding that for a court to find a constitutional right to be free of tobacco smoke --

> would be to mock the lofty purpose of such amendments and broaden their prenumbral protections to unheard-of boundaries. * * * To hold otherwise would be to invite government by the judiciary in the regulation of every conceivable ill or so-called 'right' in our litigious-minded society. The inevitable result would be that type of tyranny from which our founding fathers sought to protect the people by adopting the first ten amendments to the Constitution. Id. at 721-22.

The District Court's decision was affirmed in all respects by the United States Court of Appeals for the Fifth Circuit. The Supreme Court declined to review the decision.

Other courts likewise have rejected constitutional challenges to smoking. E.g., Federal Employees for Non-Smokers' Rights v. United States, 446 F. Supp. 181 (D.D.C. 1978), aff'd, 598 F.2d 310 (D.C. Cir.), cert. denied, 444 U.S. 926 (1979) (action to restrict smoking in federal buildings); GASP v. Mecklenburg County, 42 N.C. App. 225, 256 S.E.2d 477 (1979) (action to compel

the prohibition of smoking in county buildings and facilities). Perhaps the most novel constitutional challenge to smoking concurred in Kensell v. State of Oklahoma, 716 F.2d at 1350 (10th Cir. 1983). The plaintiff in that case alleged that his employer's refusal to provide a smoke-free workplace violated his First Amendment rights because "the smoke interfered with his ability to think." Id. at 1351. Relying on the cases discussed above, the United States Court of Appeals for the Tenth Circuit concluded that the plaintiff could prove no set of facts that would entitle him to prevail:

> We are certain * * * that the United States Constitution does not empower the federal judiciary, upon the plaintiff's application, to impose no-smoking rules in the plaintiff's workplace. To do so would support the most extreme expectations of the critics who fear the federal judiciary as a super-legislature promulgating social change under the guise of securing constitutional rights. Ibid.

TABLE OF CONTENTS

2024689097

APPENDICES

Tab 1	NIOSH IAQ Database
Tab 2	Building Performance IAQ Database
Tab 3	Medical Services Branch (Canada) IAQ Database
Tab 4	ACVA IAQ Database
Tab 5	Survey of 26 Swiss Office Buildings

1

2024689099

NIOSH IAQ DATABASE SUMMARY

I. NIOSH INDOOR AIR QUALITY INVESTIGATIONS BY YEAR (THROUGH DECEMBER 1988)

Year	Number Completed	%
Pre-1978	6	1
1978	9	2
1979	12	3
1980	28	6
1981	82	18
1982	52	12
1983	61	14
1984	56	13
1985	81	18
1986	59	13
1987	38	8
1988	45	9
Total:	529	100

While the majority of the NIOSH investigations have been conducted in government and private-sector office buildings NIOSH has also looked at schools, colleges, and health care facilities.

II. NIOSH INDOOR AIR QUALITY INVESTIGATIONS BY BUILDING TYPE (THROUGH DECEMBER 1988)

Building Type	# Completed	%
Government and Business Offices	426	80
Schools and Colleges	68	13
Health Care Facilities	35	7
Total:	529	100

Commonly, the symptoms and health complaints reported by the office workers are diverse and not specific enough for NIOSH to identify the causative agent. However, NIOSH suggests that the

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workplace environment is implicated if these symptoms normally disappear on weekends away from the office.

III. COMMON "HEALTH" COMPLAINTS: NIOSH DATABASE

Eye Irritation	Shortness of Breath
Dry Throat	Cough
Headache	Dizziness
Fatigue	Nausea
Sinus Congestion	Sneezing
Skin Irritation	Nose Irritation

Although many of these problems may be multifactorial, NIOSH classified evaluations by primary type of problem found: contamination from the building material (4%); microbiological contamination (5%); contamination from outside the building (10%); contamination from inside the building (15%); inadequate ventilation (53%); and unknown (13%). There are some considerations regarding these data, however, in that they may not fully represent a "true" cross-section of the indoor air quality problem. For example, NIOSH did not use a standard protocol for all these evaluations, as NIOSH methods and criteria have evolved over time. Also, since many of these investigations were reviewed retrospectively, there could be some misclassification due to the vagueness of earlier reports. In addition, NIOSH reports that it has little follow-up data on many of these earlier reports.

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IV. NIOSH INDOOR AIR QUALITY INVESTIGATIONS BY PROBLEM TYPE (THROUGH DECEMBER 1988)

Problem Type	# Completed	%
Building Materials Contamination	21	4
Microbiological Contamination	27	5
Outside Contamination	53	10
Inside Contamination	80	15
Ventilation Inadequate	280	53
Unknown	68	13
Total:	529	100

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Indoor air quality — the NIOSH experience

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Introduction

Health complaints associated with poor indoor air quality have been reported with increasing frequency among office workers over the past 10 years. A number of factors have contributed to this trend, including changes in building design to increase energy efficiency, introduction of new building materials, and increased awareness among workers of potentially toxic exposures in their work and home environments. While some exposures in the indoor environment may have serious implications for the health of the occupants (e.g., radon daughters, asbestos, formaldehyde, pathogenic microorganisms, allergens), the health risks of most indoor air exposures are poorly understood. Nevertheless, office workers who are concerned about a possible problem in their work environment often demand a thorough investigation of the environment and of its potential for health risks. For the investigator, this is commonly a challenging but frustrating experience because of the lack of guidelines and evaluation criteria for the "non-industrial" setting.

The health complaints reported by the occupants of the typical "problem building" are usually diverse and non-specific, and rarely point to an obvious cause. Also, the nature of the problem may be obscured by reports of a variety of serious, but unrelated, medical conditions associated with the office environment.

Appropriate environmental sampling is often quite difficult because of the presence of low levels of many ubiquitous substances. Specific contaminants from sources in the office can be readily measured and quantitated (e.g., ozone from copying machines), but more often very low levels of a variety of chemicals are detected. Such sampling results may in one sense be reassuring, but they have limited usefulness when linked with non-specific symptoms. These investigations are often complicated by extensive media coverage, multiple earlier investigations by other groups, and deteriorating labor relations. The "Federal expert" often comes into the picture when, despite much basic work having been done, the situation has reached a "crisis."

This paper will briefly present and review the indoor air quality investigations conducted by the National Institute for Occupational Safety and Health (NIOSH) since the start of the Health Hazard Evaluation Program. These investigations are being presented not as "THE WAY" to evaluate such problems, but, rather, to review our experience and share our insights as we have evolved our approach to these investigations.

Indoor air quality health hazard evaluations

Through December 1983, NIOSH has completed 203 Health Hazard Evaluations involving indoor air quality (IAQ) in a variety of settings (Table I). (This does not include our investigations of asbestos-related problems in office buildings.) Prior to 1978, only six IAQ evaluations were performed; however, since then, the number has increased dramatically. It appears that in the last 2 years, the number of these completed investigations has leveled off, but this change may reflect our handling of many IAQ inquiries by providing written materials and phone consultation, and by the increased capability of state and local health de-

TABLE I
Completed NIOSH Indoor Air Quality Investigations by Year (through December 1983)*

Year	Number Completed	%
Pre-1978	6	3.0
1978	9	4.4
1979	12	5.9
1980	28	13.8
1981	80	39.4
1982	44	21.7
1983	24	11.8
Total	203	

* Does not include [illegible] currently active projects.

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partments and other groups to handle these evaluations without our assistance.

Most of our evaluations have involved government and private offices (over 75% [see Table II]), educational institutions (14.8%), and health care facilities (9.3%). Given our mandate to evaluate occupational health problems, it is not surprising that NIOSH has not investigated very many residential IAQ problems. Thus, we do not have much experience in evaluating problems which are principally encountered in residential buildings such as exposures to radon daughters or to combustion products.

In reviewing the reports on these evaluations, we have attempted to classify our findings by the type of problem found (Table III). It is of note that nearly half of these investigations have attributed the IAQ problems to inadequate ventilation. Some form of environmental contamination was thought to be the source of the problem in approximately 30%. The source of this contamination was thought to be from inside the building in 17.7% of the investigations, outside the building in 10.3%, and from the building structure in 3.4%. Problems such as hypersensitivity pneumonitis, cigarette smoking, humidity, etc., have accounted for approximately 10% of our evaluations. Finally, in another 10%, the etiology of the IAQ problem has remained unexplained.

In reviewing these results, several factors should be considered. First, over time, NIOSH has not used a standard protocol for conducting these evaluations. Our methods and criteria have changed as we became more familiar with the problem and developed new approaches. Also, some of these investigations were conducted several years ago, leaving only scanty data and a brief report for current review. In the early studies, many of the "unknown" problems may have actually been due to inadequate ventilation, but the reports did not provide enough information to determine this. Thus, there may be considerable misclassification in this list.

TABLE II
Completed NIOSH Indoor Quality Investigations by Building Type (through December 1983)

Type	Number	%
Government and business offices	154	75.9
Schools and colleges	30	14.8
Health care facilities	19	9.3
Total	203	

TABLE III
Completed NIOSH Indoor Air Quality Investigations by Type of Problem (through December 1983)

Problem	Number	Total
Contamination (inside)	36	17.7
Contamination (outside)	21	10.3
Contamination (building fabric)	7	3.4
Inadequate ventilation	98	48.3
Hypersensitivity pneumonitis	6	3.0
Cigarette smoking	4	2.0
Humidity	9	4.4
Noise/illumination	2	1.0
Scabies	1	0.5
Unknown	19	9.4
Total:	203	

This listing is also not necessarily representative of the general distribution of indoor air quality problems in offices. Often, NIOSH is requested to conduct an evaluation only after initial attempts to identify the problem have failed or complaints have persisted after initial corrections have been made. Large public-sector agencies use NIOSH as a resource, but managers of smaller offices or office buildings may be unaware of our program. Therefore, these facilities may be underrepresented on our list. Despite these shortcomings, the list does provide an overview of the types of indoor air quality problems encountered in office environments. A brief review of the major types of IAQ problems follows.

Contamination from inside the office environment

This classification (approximately 18%) refers to exposure to a chemical or other toxic agent generated within the office space. Usually the symptoms experienced by the office worker are directly linked to the exposure, but if the exposure is disseminated through the building's ventilation system, localization of the source may be difficult. Examples from Health Hazard Evaluations include exposures to methyl alcohol from spirit duplicators,[1] exposures to methacrylate from copiers.[2]

2024689104

and exposures to sulfur dioxide from a heating system.[3] Occasionally, a very specific health effect can aid in the investigation, such as the occurrence of dermatitis from amines used in humidification systems.[4,5] The use of pest control agents, such as chlordane, may also cause persistent problems in office environments.[6,7]

These problems can usually be identified by inspecting the affected office area (e.g., copying machines) and by questioning about other uses of chemicals in the building (e.g., pesticides, humidification agents). Environmental and medical testing appropriate for that chemical can then be conducted.

Contamination from outside the building

This classification (approximately 10%) refers to exposure to a chemical or other toxic substance originating from a source outside the building. Common examples include motor vehicle exhaust either from a parking garage or loading dock entering the building through the intake from the ventilation system.[8,9] Many of these exposures are "presumed" explanations that cannot be documented at the time of the investigation. Although the dispersal of substances through the ventilation system may seem obvious, the complexity of the system may require the use of more sophisticated techniques such as a tracer gas to document the problem.[8] Other outside sources include nearby construction activity which may generate sufficient exhaust fumes, dust, or other contaminants to cause complaints in nearby offices.[10]

A few years ago, NIOSH evaluated a dramatic case of outside contamination of an office building when we discovered a 6-million-gallon underground gasoline spill while investigating irritative symptoms among the office occupants.[11] While this may be viewed as unusual, there is concern about the increasing number of underground gasoline tank leaks.

Contamination from the building fabric

Contamination from the building fabric (approximately 3% of our evaluations) refers to problems from the material used to construct the building. While not included in our list of evaluations, asbestos is obviously a major source of concern about indoor air quality. Other insulating materials are a common source of these problems because of the release of substances such as formaldehyde.[12] Dermatitis due to fibrous glass has also been a common problem, usually after the fibrous glass insulation has been disturbed during some construction activity.[13]

Hypersensitivity pneumonitis

This group (approximately 5% of our evaluations) refers to problems due to a hypersensitivity reaction to microorganisms in the building environment. Although not a common cause of office problems, the potential medical severity of this condition and the difficulties in controlling this problem make it an important cause of office problems. NIOSH's evaluations regarding this problem will be discussed later in this volume.

Inadequate ventilation

By far the largest classification, this group makes up approximately one-half of our completed evaluations. Our determination of inadequate ventilation is commonly made after considering a number of factors, including the absence of other sources of contamination and the presence of only very low levels of contaminants in our environmental sampling results. These, linked to the widespread occurrence of non-specific symptoms such as headaches, eye irritation, and upper respiratory irritation, suggest that an evaluation of the ventilation system may be warranted.

The evaluation of ventilation systems will be discussed later. Our methods range from obtaining specifications on the building ventilation system to detailed air flow measurements. Both approaches can present difficulties. Information on the specifications of the ventilation system is often not readily available from the building operators. Buildings with renovated ventilation system are often very difficult to evaluate because of the piecemeal approach used in such renovation. The ASHRAE guidelines for ventilation are usually used for comparison.[14] While one can question the basis for these guidelines, we have found them useful in evaluating IAQ problems and for recommending corrections where there is a problem because of inadequate ventilation.

The pathogenesis of complaints or symptoms caused by inadequate ventilation is not clear, but certain extreme situations have provided us with some insight into the relationship between such complaints and inadequate ventilation. In 1982,

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we conducted an evaluation at a government office building in Idaho with widespread complaints among the employees. Despite environmental surveys showing no significant comtaminant levels, the employees were moved to another building. Our investigators found that the air intake for the building had been covered with plastic one year earlier, to protect the air handling system from airborne debris from Mount St. Helens, and that this cover had never been removed. Removal restored intake of adequate outdoor air to the building and allowed reoccupancy without significant problems.[15] However, in this situation, no environmental measurement indicated that there was a problem. In general, we have not found any environmental measurement to be useful as an indicator of poor ventilation. However, it should be noted that other investigators have found carbon dioxide levels useful for such evaluations.[16,17] Low levels of multiple contaminants are often present in these situations and are currently the best explanation for the occurrence of symptoms. The pattern of contaminants probably varies from building to building, but we do not yet have adequate measurement techniques or adequate knowledge to easily recognize this problem through environmental sampling.

Current evaluation methods

Our current approach to evaluating office environment requests usually begins with a walk-through evaluation by an industrial hygienist. Prior to this, we try to obtain background information on the history of the building design or construction and try to ensure that the building engineer will be present during the investigation. During the initial visit, we obtain a history of complaints among office occupants by interviewing as many as is feasible. This is helpful not only for identifying the type of medical complaints, but also for obtaining a chronology of the problem and ascertaining the time pattern of symptoms (afternoon more than morning, etc.).

Potential sources of contamination are identified during the initial walk-through evaluation. Some will be obvious (e.g., copying machines), while others may be identified only after careful questioning (e.g., pesticide spraying). We also usually inspect the ventilation system for the particular office area and attempt to understand its connection to the system for the entire building. Information on the control of the ventilation system (outdoor air intake relative to temperature, etc.) is also obtained. Some environmental sampling may be conducted if a source of contamination is found or suspected. Some general air monitoring (e.g., organics) may also be conducted, but this is usually more helpful to reassure the occupants that the toxic substances of concern to them are not present in any degree than it is for identification of a problem.

The problem may be resolved during this initial visit, but, in some instances, more extensive environmental sampling, a medical study, a ventilation assessment, or some combination of these may be required. These may be necessary either to better identify the source and extent of the problem or to alleviate the concerns of the affected employees. Once our investigations are complete, our findings and recommendations are communicated to the involved parties.

Future activities in indoor air quality

More research into office ventilation and its effect on background levels of contaminants is necessary to provide better guidelines for evaluating and controlling indoor air quality problems. Because of the nature of these exposures, a variety of governmental agencies and private groups are involved in this research effort. Recently, the Environmental Protection Agency, the Consumer Product Safety Commission, the Department of Energy, the Department of Health and Human Services, the Tennessee Valley Authority, and several other Federal agencies formed a coordinating committee on indoor air quality research. This committee will help to coordinate Federal government indoor air quality research. Already, an inventory of IAQ-related research in the Federal government has been prepared. These agencies are also coordinating the planning of a possible large national survey of indoor air pollution and related health problems.

While much of this effort and related research may seem remote to investigating specific problems in office buildings, they may provide the basis for better guidelines for evaluating indoor air quality and for necessary corrective steps. At the same time, improved methods of assessment are needed to evaluate specific types of problems.

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NIOSH is currently developing better methods for assessing indoor air quality (e.g., microorganism levels, ventilation parameters, etc.). Other groups are working on methods for other types of assessments. Meanwhile, we will continue to evaluate indoor air quality problems and, hopefully, continue to improve our efforts in these assessments.

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INDOOR AIR QUALITY

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National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer
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Mention of the name of any company or product, or inclusion of a particular reference does not constitute endorsement by the National Institute for Occupational Safety and Health.

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) has compiled this document in response to an increasing number of requests for information about indoor air quality (IAQ), including "sick building syndrome." Included in this publication are:

1. NIOSH Congressional testimony that describes the NIOSH IAQ investigations program and summarizes the results of NIOSH research and findings on IAQ problems;

2. NIOSH guidance for conducting indoor air quality investigations;

3. NIOSH journal article on evaluating building ventilation systems; and

4. List of non-NIOSH publications on indoor air quality.

As the Federal agency responsible for conducting research and making recommendations for occupational safety and health standards, NIOSH limits its IAQ activities to the occupational environment. The U.S. Environmental Protection Agency (EPA) also conducts an IAQ program and can be contacted for information regarding both occupational and non-occupational settings. Several relevant EPA publications are included in Item 4 above and can be obtained from the EPA Public Information Center, 401 M Street S.W., Mail Code PM 211B, Washington, DC 20460, telephone 202-382-2080.

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CONGRESSIONAL TESTIMONY

TESTIMONY OF

J. DONALD MILLAR, M.D.

DIRECTOR

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

CENTERS FOR DISEASE CONTROL

Before the

SUBCOMMITTEE ON SUPERFUND, OCEAN AND WATER PROTECTION

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

May 26, 1989

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I am Dr. J. Donald Millar, Director of the National Institute for Occupational Safety and Health (NIOSH) of the Centers for Disease Control, in the Public Health Service of the Department of Health and Human Services. I appreciate this opportunity to report to you on the activities of NIOSH in the area of indoor air quality.

Our experience with evaluating and understanding indoor air quality problems is based on the research and technical assistance that we have conducted under the mandates of the Occupational Safety and Health Act (OSH Act). Our knowledge, therefore, relates to the health effects on workers in nonresidential and nonindustrial workplaces, including Federal buildings, schools, and other public buildings, commercial buildings and portions of commercial vehicles occupied by workers. In addition to dealing with air quality, this knowledge base includes data on ergonomic and psychosocial problems that also affect workers.

More specifically, most of our knowledge on indoor air quality problems has been generated on the "technical assistance side" of our responsibilities under the OSH Act. This assistance is conducted under Section 20(a)(6) of the OSH Act through our Health Hazard Evaluation (HHE) Program, where we respond to requests from employers, employees, employee representatives, State and local agencies and other Federal agencies. Presented below is a brief narrative of how the HHE Program is utilized for indoor air quality investigations, and what we have learned from these investigations in regard to the extent of the problem. Additional details are shown in Enclosure I.

In the 1970's, following the Arab oil embargo, energy conservation programs were encouraged throughout the United States. The operations of buildings changed in an effort to conserve fossil fuels and operating costs. Ventilation rates were reduced and buildings were sealed to prevent infiltration of untempered outside air (hot, humid air in the summer months and cold, dry air in the winter months). At the same time, there was a revolution occurring in buildings throughout the country. Computers forced a change in office procedures and productivity leading to ergonomic and organizational stress problems. Some of these new office technologies brought with them chemical and physical hazards.

We saw the effect of the conservation measures, as well as problems associated with the shifts in office automation (e.g. video display terminals, vision problems), and concern about asbestos and radiation, through increases in requests for assistance in the HHE Program. Of the 1,200 Health Hazard Evaluations between 1971 and 1978, NIOSH investigated six indoor air quality problems or 0.5% of the total. From 1978 to 1980, the percentage of HHE's have averaged 12% of all health hazard evaluations. More recently, on an annual basis, this has increased to approximately 20%. For example, in FY 1988 through the present, NIOSH's toll free information number has received an average of approximately 60 inquiries and requests for assistance per month on indoor air quality problems. In 1988, in addition to providing background information and a copy of NIOSH's indoor air quality guidance document (Enclosure I) to most of these callers, NIOSH researchers conducted 45 field investigations.

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Table 1 presents the number of HHE investigations by building type since the Program was initiated in 1971. (These totals do not include complaints arising from asbestos contamination--the number of which also is significant--or complaints regarding radon.)

TABLE 1

NIOSH Indoor Air Quality
Investigations by Building Type
(through December 1988)

Building Type	Number Completed	Percent of Total
Government and Business Offices	426	80
Schools and Colleges	68	13
Health Care Facilities	35	7
Total:	529	100

We have not seen a decrease in indoor air problems and we are concerned that as the U.S. moves more and more to a service and information economy, with increases in office workers, the problems will increase.

Indoor air quality problems may arise from a variety of sources including human metabolic activity, smoking, structural components of the building and contents, biological contamination, office and mechanical equipment, and outside air pollutants that enter the building. Commonly, the symptoms and health complaints reported by workers are diverse and not specific enough to readily identify the causative agent (Table 2). The workplace environment is implicated by the fact that these symptoms can be severe enough to result in missed work, reassignment, and even termination. This causes increased anxiety among the workers and, often times, makes the investigation of these problems even more difficult.

TABLE 2

Common Health Complaints

Eye Irritation
Dry Throat
Headache
Fatigue
Sinus Congestion
Skin Irritation
Shortness of Breath
Cough
Dizziness
Nausea
Sneezing
Nose Irritation

Although some of these episodes may be made up of several factors combined, we have classified the results found in our HHE Program by primary type of problem found: contamination from the building materials (4%); microbial contamination (5%); other contamination from inside the building (15%); contamination from outside the building (10%); inadequate ventilation (53%); and unknown (13%).

As mentioned above, in over half of our indoor air quality investigations, inadequate ventilation was found to be the cause of complaints. Heating, ventilating, and air conditioning (HVAC) conditions that can cause indoor air quality problems include migration of odors or chemical hazards between building areas, re-entrainment of building exhaust through heat recover devices or improper placement of exhaust and intake stacks, buildup of microorganisms in HVAC system components and poor odor and environmental control due to insufficient "fresh" outdoor air. The insufficient use of "fresh" outdoor air has been compounded by reduction in ventilation airflows because of energy conservation. The inadequacy of building ventilation can be evaluated by monitoring ambient carbon dioxide (CO_2) concentrations, temperature, humidity, and airflow. However other chemical agents from sources other than human occupants also increase with adequate building ventilation.

In 20-25% of our indoor air quality surveys, sources inside the building have been identified as the major generators of indoor air pollution. To date, common sources that have been identified include: duplicators-methyl alcohol; signature machines - butyl methacrylate; blueprint copiers--ammonia; acetic acid; pesticides; boiler additives--diethyl ethanolamine; cleaning agents; tobacco smoke and combustion gases; foam insulation, particle board, plywood, construction glues and adhesives--formaldehyde, and organic solvents; lined ventilation ducts--fibrous glass; silicone caulking and curing agents. In these situations, we have found that low concentrations of agents need to be monitored since odor thresholds, comfort and unusual stimuli may be the significant factors rather than higher concentrations where health effects have been established. Also, in many instances no evaluation criteria exist and the investigators must compare areas where complaints are frequent with areas which have no complaints to search for chemical, biological, physical, and organizational factors which may be the cause. Given the problems with identifying emission sources and the need to measure at low levels, sensitive and specific direct-reading instruments need to be followed with highly specific, low level chemical analysis in the laboratory.

To complicate the investigations concerning poor air quality, ergonomics and psychosocial issues often are encountered. For example, our research teams, composed of behavioral scientists, physicians and industrial hygienists, have investigated a series of mass illness outbreaks in various work settings for which there was no apparent physical or chemical cause. The reported symptoms are typically vague and nonspecific, and frequently are described by workers as ill defined contaminants in the workplace (e.g., bad odors, stuffy or heavy air). Questionnaire surveys and interviews of both affected and unaffected workers suggest that the expression of the symptoms may have been exacerbated by a variety of ergonomic, organizational and psychosocial stresses which increase worker job and life-dissatisfaction.

Aside from NIOSH experiences discussed above, there have been considerable activities by other governmental and nongovernmental groups worldwide of which I am sure you are aware. Some major examples of these are as follows;

1. The National Research Council's Assembly of Life Science published "Indoor Air Pollutants" in 1981. The report lists a number of chemicals implicated in indoor air pollutant problems without assessing their importance. The Assembly also recommended that monitoring protocols and special instruments be developed to asses indoor air pollutants; that complaints of malaise, headache, stuffiness, and eye and throat irritation be studied; that the lowering of work productivity due to indoor pollution and associated discomfort be investigated; and that the influences of building design on the concentration of pollutants in commercial facilities be conducted.

2. The Environmental Protection Agency (EPA) published "EPA Indoor Air Quality Implementation Plan" in 1987 which not only described EPA's research agenda at that time, but dealt with those indoor air quality issues that concerned other Federal agencies. The document included a bibliography of indoor air quality literature containing over 2,000 entries.

3. In 1988, the Health and Safety Executive of Great Britain issued a report "Sick Building Syndrome: A Review." This report summarizes their experiences with "sick building syndrome," and discusses symptoms, common features of "sick buildings" and possible causes. Their experiences mirror that information found by our HHE Program.

4. A 1988 EPA publication, "Indoor Air Quality in Public Buildings" reported that concentrations of volatile organic compounds in new buildings were found to be as much as 100 times higher than those found outdoors.

5. Volume II of the Environmental Protection Agency's Report to Congress prepared in 1988/89 under Title IV of the Superfund Amendments and Reauthorization Act of 1986 highlights an up-to-date summary of the "Assessment and Control of Indoor Air Pollution." This volume discusses such issues as (a) factors affecting indoor air quality; (b) sources of pollutants and health effects; and (c) economic impacts.

These examples support the point that indoor air quality problems associated with worker health are significant and require continued vigilance.

In regard to your questions pertaining specifically to the Indoor Air Quality Act (S.657), the Administration has not yet taken a position on the specific contents of the proposed legislation.

Thank you for the opportunity to submit this testimony to the record.

ENCLOSURE I

THE NIOSH APPROACH TO CONDUCTING INDOOR AIR QUALITY INVESTIGATIONS IN OFFICE BUILDINGS

National Institute for Occupation Safety and Health

ABSTRACT

Since 1971, personnel from the National Institute for Occupation Safety and Health (NIOSH) have complete over 500 indoor air quality (IAQ) investigations in a variety of office building environments. Most of these investigations have been conducted since 1979, paralleling the energy conservation concerns of building owners and operators. These investigations have been conducted under the authority of the NIOSH Health Hazard Evaluation Program and have been in direct response to reported health complaints or illness. Therefore, these IAQ investigations are intended to establish the identity of a problem and to recommend solutions for its correction. Over time, we have developed a consistent methodology with a "solution-oriented" approach to conducting these IAQ investigations. To initiate the investigation, the NIOSH team gathers background information by telephone and then makes a site visit to interview the affected employees and establish symptom identity and prevalence. During this initial site visit, the investigators also attempt to identify sources of contaminants, evaluate comfort parameters, and assess ventilation system performance. A variety of applicable evaluation criteria may be used, including "rules-of thumb" gleaned from the current scientific literature and our own experiences. If specific problems cannot be identified through these initial means, follow-up visits are then used to pursue a continually narrowing range of possibilities. This "solution-oriented" approach has resulted in the best allocation of our resources and has allowed the most efficient use of in-field as well as analytical personnel. In the IAQ investigations completed to date, problems were found to result from building material contaminants in 4%, microbiological contaminants in 5%, contaminants brought in from outside the building in 10%, contaminants from inside the building in 15% and inadequate ventilation problems in 53%. The remaining 13% represent those investigations where no problem could be identified.

INTRODUCTION

The sometimes questionable quality of indoor air and the potential for health risks have become major concerns of building occupants, especially office workers. Some potential indoor exposures, such as to the carcinogen, asbestos, have well-documented health implications. But, more commonly, the health risks of other indoor air exposures are poorly understood. Nevertheless, office workers experiencing indoor air quality (IAQ) problems often demand a complete evaluation of their work environment and of the effect it may have upon their health.

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At the National Institute for Occupation Safety and Health (NIOSH), the majority of our indoor air quality investigations are conducted as part of the Health Hazard Evaluation Program. We conduct these health hazard evaluations at the request of employee groups, unions, management, and local, State and Federal agencies. Generally, these requests are in response to existing worker health complaints and illness. Because we are essentially "invited" to conduct these investigations, the data presented here will not reflect a statistically valid cross-section of the indoor air quality problem. However, these findings are drawn from one of the largest single information bases currently available on the subject. In essence, this paper will summarize the NIOSH methodology currently used during IAQ investigations and some of the data from these IAQ investigations completed since the start of the Health Hazard Evaluation Program.

METHODOLOGY

We have found that investigating IAQ problems can present a formidable challenge which, in some ways, is more difficult than evaluating industrial environments. In an industrial situation, the evaluation will be directed by investigations of the materials used by, or in the vicinity of, the affected workers. These materials can usually be chemically analyzed which permits techniques and potential health effects using standard medical and epidemiologic techniques. Frequently there are exposure criteria which can be applied to help interpret the data obtained. This is rarely the case with an indoor air quality problem.

Indoor air quality investigations tend to become more complicated as time passes without identification of a cause. Frustrations result in highly charged emotions which only further impede continued evaluation efforts. These situations are further complicated by the fact that symptoms are not easily attributed to a single cause and the application of standard industrial hygiene, medical and epidemiologic techniques may prove to be inconclusive.

Over time, our approach in evaluating this situation has changed. We have developed a more consistent, solution-oriented approach that systematically excludes a continually narrowing range of possibilities. Generally, this exclusion hierarchy, which has come about based on our past experiences, involves evaluation of physical, chemical and microbiological factors, in the order presented. Each of these potential causation categories are discussed in more detail later in this presentation.

Since we anticipate that IAQ requests will continue to represent a substantial percentage of the total health hazard evaluation requests (currently about 20%), three response levels have been developed. Based on the information obtained during initial telephone with the requestor, the following responses are possible:

1. Provide "self-help evaluation" materials (attached). Remain available for consultation by telephone. Become more involved, if necessary.

2. NIOSH conducts an initial evaluation an provides recommendations to solve the problem or for further study on a "self-help" basis.

3. NIOSH conducts a full scale investigation.

The NIOSH investigation team commonly includes an industrial hygienist and physician/epidemiologist, but can also include other professionals such as an engineer. Most investigations contain the following parts: background assessment, initial site assessment, and, if necessary, additional site assessment.

BACKGROUND ASSESSMENT

For the background assessment, we initially obtain, by telephone, as much information on the building as practicable, an idea of symptoms being experienced, and a chronology of the problem. Much of this information can be collected using a standard questionnaire. We also request copies of other previous investigations which are relevant to the problem at hand. These data are then used to tailor the protocol for the initial site assessment so as to make it more efficient.

INITIAL SITE ASSESSMENT

For the initial site assessment, a common protocol includes five separate steps or parts: an opening conference, a walk-through evaluation, personal interviews, phase I of environmental monitoring, and a closing conference.

Opening Conference--The opening conference is attended by representatives of the employer and employees (where applicable) as well as someone who has knowledge of the operation, and maintenance of the building's heating, ventilating and air conditioning (HVAC) systems. This meeting serves to present NIOSH's role, discuss anticipated activities and arrange to receive copies of pertinent data not already received.

Walk-through Survey--The walk-through survey will involve all or part of the building including inspection of the HVAC systems with special attention given to the mechanism by which outside air enters each HVAC unit. Architectural plans and ventilation test and balance reports may also be reviewed during this phase. Potential sources of emission are identified so that each may be further evaluated, as needed.

Personal Interview--Personal interviews are often conducted to determine the extent, prevalence and character of reported symptoms. The use of a questionnaire, such as the one shown in Appendix 1, may be the most efficient means of collecting this type of information. It can be used as a guide during personal interviews or it can be self-administered

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Phase I Environmental Monitoring--Phase I environmental monitoring is usually conducted on each initial survey. The scope of this effort may vary, but usually will either evaluate certain aspects of the building environment, which we have come to believe are important factors in all investigations, or explore any other possibilities made apparent from the background assessment. Evaluation of the ventilation system using both actual measurement and/or carbon dioxide (CO2) techniques, and monitoring temperature and relative humidity are useful procedures for all evaluations during the initial site assessment. Monitoring for formaldehyde is an example of a specific method which may be used if the background assessment indicates that respiratory system and eye irritation are prevalent complaints and the space has been recently built or renovated (a number of furnishings are potential sources of formaldehyde). Most of the monitoring accomplished on the initial survey is obtained using direct-reading instruments where possible because they provide results on-the-spot. Any deficiencies noted can be corrected and re-evaluated. Trace concentrations of hundreds of compounds could be identified depending on the extent of the sampling and analytical effort; however, the concentrations usually detected would not be expected to cause adverse health effects in a normal healthy individual. Other techniques which I will now discuss have been consistently more useful.

Evaluating HVAC Systems--HVAC systems can be complicated and most industrial hygienists have received very little or no training in the design, maintenance and trouble-shooting of building ventilation systems. The most important aspect of evaluating HVAC systems is to gain an understanding of how they are supposed to be working and then use some relatively simple methods to convince yourself that the system is performing up to the design specifications, and whether this is adequate with respect to the complaint areas in the building, return to the complaint area(s) and measure supply and return air flows using either a velometer or a flow hood and compare the results to the design quantities. Note that in variable-air-volume (VAV) systems the supply air flows may vary during the day.

A method which is gaining popularity, and which is currently used by NIOSH for evaluating the adequacy of ventilation to an area is the measurement of CO2 concentrations. Humans expire significant quantities of CO2. The higher the CO2 levels inside a building, the poorer the overall ventilation, in a general sense. We believe that complaints will not be prevalent if interior CO2 concentrations are maintained at twice or less the outdoor levels (usually 250-300 ppm). At CO2 concentrations above 1000 ppm, or 3 to 4 times the outdoor level, complaints of headaches tiredness, eye, nose and throat irritation may be more prevalent. It is important to realize that it is not the CO2 concentration that is causing the symptoms; but, if CO2 increase, so may all the other normal airborne contaminants and it may be some combination of all these substances that make people uncomfortable. Carbon dioxide measurement scan be obtained using standard detector tubes or portable CO2 monitoring instruments. The use of CO2 as an index of the general quality of indoor air is currently being evaluated by NIOSH as well as many other agencies.

Poor mixing of air is another potential problem sometimes found when air is delivered and returned through ceiling diffusers. Standard smoke tubes, and temperature and CO_2 measurements at 1 foot and 7 foot heights above the floor may be useful techniques in evaluating stratification resulting from poor mixing.

Monitoring Temperature and Relative Humidity--Temperature too cold, too warm or fluctuating can be a source of complaints. While individuals vary in their limits of thermal comfortability, if a significant number of workers in an area complain (more than 20%), then temperature and relative humidity may be creating an uncomfortable environment. If temperatures are too warm, complaints or tiredness, lack of concentration and headache may also be reported. Low relative humidities, not uncommon in the winter in a building or residence that is not humidified, can cause eye, nose and throat irritation.

CLOSING CONFERENCE

The closing conference of the initial site survey provides an opportunity to present the NIOSH activities accomplished, any results obtained and recommendations on corrective actions if potential problems were identified. If no problems were identified, recommendations may be made on how to continue studying the problem either on a self-help basis or through continued NIOSH involvement. Typical recommendations when we have not identified a probable explanation for the reported symptoms would include the formulation of a more formalized method of reporting worker symptoms on a daily basis and the generation of HVAC data logs to provide evidence that the HVAC system is performing in a consistent manner over time.

EVALUATION CRITERIA

Evaluation criteria used to interpret environmental measurements vary. In the classic industrial hygiene sense, the Occupational Safety and Health Administration's (OSHA) permissible limits [1], the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values [2], and NIOSH's recommended exposure limits [3] are most commonly used in occupational exposure assessments. Because these criteria are based on health effects as they pertain to the manufacturing environment, they may not have the same relevance for workers in an office setting, whose primary concern may be for comfort or simply an absence of unusual sensory stimuli over their working period. The Environmental Protection Agency (EPA) has ambient air quality standards [4] for a variety of pollutants designed to protect the public over an entire day (not just an 8-hour workday). However, these, too, may not have relevance to an indoor office environment, especially from the perspective of problem-solving.

The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) guidelines for acceptable indoor air quality [5] have been developed for the indoor environment. We commonly use these as criteria in our office building evaluations, especially for assessing the performance of a ventilation system. We also use the ASHRAE comfort guidelines [6] as criteria for assessing the thermal performance of occupied space.

ADDITIONAL SITE ASSESSMENTS

If the background assessment and the initial site visit identify a problem that need further definition, or if no problem can be isolated, an additional site assessment may be performed. During the additional site assessment, more specific and extensive monitoring may be conducted for chemical and/or microbiological contaminants of interest. Sampling for airborne microbiological contaminants is also outside of what is considered a standard industrial hygiene technique. Useful techniques are still under evaluation. Methodology is available; however, analytical support is somewhat limited. Nevertheless, the topic of potential microbiological contamination usually comes up as an investigation progresses. Close visual inspection of the various HVAC components will usually uncover a microbiological problem if present.

The condition most commonly associated with exposure to airborne organisms is hypersensitivity pneumonitis. This is a general term for a disease which occurs as a result of an immunologic inflammatory reaction to the inhalation of any of a variety of organic dusts. Terms like humidifier fever, ventilation pneumonitis, farmer's lung and cheese worker's lung are all the result of these exposures. Symptoms are usually described as a recurring "flu-like" syndrome. Diagnosis is based on a combination of characteristic symptoms, chest x-rays, pulmonary function abnormalities and sometimes immunologic studies [7].

Inspection of the HVAC system and confirmation of the diagnoses of hypersensitivity pneumonitis among workers may be more useful than air sampling for airborne microorganisms until investigative techniques are further refined.

DISCUSSION

Through December 1988, 529 NIOSH indoor air quality health hazard evaluations have been completed (Table 1). These do not include our investigations of asbestos-in-building problems, but only those where the building occupants were actually experiencing ill health effects. The number of investigations has increased markedly since 1979. This is most probably due to a couple of factors: increased energy conservation measures and increased worker awareness of their office environment. We now average about two indoor air quality investigations per week.

TABLE 1

NIOSH INDOOR AIR QUALITY INVESTIGATIONS
BY YEAR (THROUGH DECEMBER 1988)

Year	Number Completed	%
Pre-1978	6	1
1978	9	2
1979	12	3
1980	28	6
1981	82	18
1982	52	12
1983	61	14
1984	56	13
1985	81	18
1986	59	13
1987	38	8
1988	45	9
Total:	529	100

While the majority of our investigations have been conducted in government and private-sector office buildings (Table 2), we have also looked at problems in schools, colleges, and health care facilities.

TABLE 2

NIOSH INDOOR AIR QUALITY INVESTIGATIONS
BY BUILDING TYPE (THROUGH DECEMBER 1988)

Building Type	# Completed	%
Government and Business Offices	426	80
Schools and Colleges	68	13
Health Care Facilities	35	7
Total:	529	100

Commonly, the symptoms and health complaints reported by the office workers are diverse and not specific enough to readily identify the causative agent (Table 3). The workplace environment is implicated by the fact that these symptoms normally disappear on weekends away from the office. At times, these symptoms can be severe enough to result in missed work, reassignment, and even termination. This causes increased anxiety among the workers and, often times, makes the investigation of these problems even more difficult and frustrating.

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TABLE 3

COMMON HEALTH COMPLAINTS

Eye Irritation	Shortness of Breath
Dry Throat	Cough
Headache	Dizziness
Fatigue	Nausea
Sinus Congestion	Sneezing
Skin Irritation	Nose Irritation

Although many of these problems may be multifactorial, we have classified our evaluations by primary type of problem found: contamination from the building material (4%); microbiological contamination (5%); contamination from outside the building (10%); contamination from inside the building (15%); inadequate ventilation (53%); and unknown (13%) (Table 4.) There are some shortcomings to these data, however, in that they may not represent a "true" cross-section of the indoor air quality problem as previously discussed. For example, we have not used a standard protocol for all these evaluations, as our methods and criteria have evolved with time and experience. Also, since many of these investigations were reviewed retrospectively, there may be some misclassification due to the vagueness of earlier reports. Lastly, we have little follow-up data on many of these evaluations to enable us to determine the efficacy of our recommendations[8].

TABLE 4

NIOSH INDOOR AIR QUALITY INVESTIGATIONS
BY PROBLEM TYPE (THROUGH DECEMBER 1988)

Problem Type	# Completed	%
Building Materials Contamination	21	4
Microbiological Contamination	27	5
Outside Contamination	53	10
Inside Contamination	80	15
Ventilation Inadequate	280	53
Unknown	68	13
Total:	529	100

BUILDING MATERIALS CONTAMINATION

Contamination from building materials and products was the major problem in 4% of our investigations. Formaldehyde can off-gas from urea-formaldehyde foam insulation, particle board, plywood, and some glues and adhesives commonly used during construction. Other building fabric contamination problems encountered included dermatitis resulting from fibrous glass, various organic solvents from glues and adhesives, and acetic acid used as a curing agent in silicone caulking.

MICROBIOLOGICAL CONTAMINATION

Five percent of our investigations have involved some type of microbiological contamination. Even though this is not a common cause of office problems, it can result in a potentially severe condition known as hypersensitivity pneumonitis. This respiratory problem can be caused by bacteria, fungi, protozoa, and microbial products that may originate from ventilation system components. A similar condition known as humidifier fever, most commonly reported in Europe, is also a result of microbiological contamination in ventilation systems. In our investigations, microbiological contamination has commonly resulted from water damage to carpets or furnishings, or standing water in ventilation system components.

OUTSIDE CONTAMINATION

Contamination from sources outside the office space was the major problem identified in 10% of our investigations. Problems due to motor vehicle exhaust, boiler gases, and previously exhausted air are essentially caused by re-entrainment. This is usually the result of improperly locked exhaust and intake vents or periodic changes in wind conditions. Other outside contamination problems include contaminants from construction or renovation such as asphalt, solvents, and dusts. Also, gasoline fumes infiltrating the basement and/or sewage system can sometimes be a problem and are usually caused by gasoline leaks from ruptured underground tanks at nearby service stations. One of the most common sources of outside contamination has been carbon monoxide fumes from basement parking garages being recirculated through the building ventilation system.

INSIDE CONTAMINATION

Contamination generated by sources inside the office space was the major problem identified in 15% of our investigations. Copying machines are often found to be a significant source. Examples of this type of problem would include methyl alcohol from spirit duplicators, butyl methacrylate from signature machine and ammonia and acetic acid from blueprint copiers. Still other inside contamination problems we have encountered include pesticides which were improperly applied; dermatitis from boiler additives such as diethyl ethanolamine; improperly diluted cleaning agents such as rug shampoo; tobacco smoke of all types; combustion gases from sources common to cafeterias and laboratories; and cross-contamination from poorly ventilated sources that leak into other air handling zones.

Contaminants from inside or outside the office space, and from the building fabric are essentially chemical contaminants. Many times odors are associated with some of these contaminants which may aid in source identification. Additionally, in most cases, these chemical contaminants were measured at levels above ambient but far below any existing occupational standard.

INADEQUATE VENTILATION

In 53% of our investigations, the building ventilation has been inadequate. When evaluating building ventilation, we normally use ASHRAE standards for comparison. ASHRAE standards 62-1981, "Ventilation for Acceptable Indoor Air Quality" (ASHRAE 1981) and 55-1981, "Thermal Environmental Conditions for Human Occupancy" (ASHRAE 1981) are both used. Some of the ventilation problems we commonly encounter are: not enough outdoor air supplied to the office space; poor air distribution and mixing which causes stratification, draftiness, and pressure differences between office spaces; temperature and humidity extremes of fluctuations (sometimes caused by poor air distribution); and air filtration problems caused by improper or no maintenance to the building ventilation system. In many cases, these ventilation problems are created or enhanced by certain energy conservation measures. These include reducing or eliminating outdoor air; reducing infiltration and exfiltration; lowering thermostats in winter, raising them in summer; eliminating humidification or dehumidification systems; and early shut-down and late start-up of ventilation systems.

CONCLUSION

The major problems identified in these NIOSH indoor air quality investigations can be placed into three general categories listed with decreasing frequency: inadequate ventilation, chemical contamination, and microbiological contamination. Inadequate ventilation is the single largest problem we have seen in buildings. Although varied, these ventilation problems commonly can allow a build-up of any contaminants present in the occupied space to the point that adverse health effects are experienced or allow the environment to become annoyingly uncomfortable to the office workers. As our experience increased over time, we developed a solution-oriented approach to conducting these evaluations which places a high priority on building ventilation. This approach has resulted in the best allocation of our resources and has allowed more efficient use of in-field as well as analytical time.

Increasing office worker awareness and the current shift to office-based, service-type employment will no doubt increase concerns about the indoor air quality in offices and other non-industrial settings. More research into office building ventilation and its effect on background levels of contaminants will be necessary to provide additional and more appropriate guidelines for the evaluation and control of indoor air quality problems in the future.

Early recognition of a problem, with a timely and systematic evaluation, are key factors to a quick and effective resolution.

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2

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APPENDIX II

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BUILDING PERFORMANCE
DATABASE (STERLING, ET AL.)

I. INVESTIGATOR'S CONCLUSIONS FROM REPORTS CONTAINED IN THE BUILDING PERFORMANCE DATABASE

SUSPECTED CAUSE IDENTIFIED	NUMBER	PERCENT
VENTILATION CONTROL PROBLEM	159	39.0%
- lack of outside air		
- poor air distribution		
- poor temperature control		
- operational deficiency		
VENTILATION INFILTRATION PROBLEM	40	10.0%
- reentry of exhaust fumes		
- outside infiltration		
INDOOR SOURCES		28.1%
- offgassing from building materials	27	
- printshops/duplicators	17	
- microbial	14	
- smoking	12	
- fibrous insulation	8	
- chemical storage	6	
- cleaning solvents	6	
- pesticides	5	
- lighting	5	
- refrigerant spill	4	
- carpet shampoo	4	
- other (boilers, water leaks, etc.)	7	
STRESS	12	2.9%
ERGONOMIC/WORKSTATION DESIGN	5	1.2%
UNDETERMINED CAUSE	42	10.2%
NO PROBLEM IN BUILDING	35	8.6%
TOTAL:	408	100.0%

II. VENTILATION RELATED PROBLEMS

"Ventilation Related" inadequacies are the most commonly reported cause of problems in buildings. A differentiation can be made between problems of "control" and "infiltration."

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PRESENT AND FUTURE OF INDOOR AIR QUALITY

Proceedings of the Brussels Conference,
14–16 February 1989

Editors:

C.J. Bieva, Y. Courtois and M. Govaerts

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FOREWORD

Indoor air quality conservation and procedures for the measurement of related potential pollutants, such as radon, asbestos, gases, pesticides, tobacco smoke and bacteria from air conditioning systems, have seen important changes in recent years, while the range and the scope of the studies have continued to expand.

In addition to helping preserve public health, the field of interest is now extending to include such areas as architectural design, ventilation engineering, sociology, psychology and legal aspects. Related analytical techniques like gas chromatography and mass spectroscopy have undergone parallel refinements and their range of application has broadened.

These advances were discussed at the Conference 'Present and Future of Indoor Air Quality', held in Brussels, February, 1989, following symposia on indoor air quality at Essen and Tokyo in 1987 and London in 1988. The sessions were attended by about 200 scientists representing 20 countries. A total of 92 papers and posters were presented covering such topics as pathogenesis and epidemiology, sources of indoor air contamination and risk assessment, chemistry of indoor air related to the outdoor air quality, social and psychological aspects of poor indoor air quality, motivation and attitudes, future guidelines for the improvement of indoor air quality through architectural and ventilation design, and air quality monitoring.

The proceedings include full texts and posters presented during the meeting. The organising committee hopes that they will constitute a useful guide for the improvement of our indoor air quality in the future.

CONTENTS

OPENING SESSION: RISK ASSESSMENT AND HEALTH

SECTION 1: ETS AND PASSIVE SMOKING

SECTION 4: INDOOR AIR QUALITY: PREVENTION AND FUTURE GUIDELINES

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Present and future of indoor air quality.
C.J. Bieva, Y. Courtois, M. Govaerts, editors

A DATABASE OF PROBLEM BUILDINGS: LEARNING BY PAST MISTAKES

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INTRODUCTION

An implicit objective of the designers of modern office buildings is the creation of a "healthy" work environment, one in which building occupants are satisfied with indoor environmental conditions. However, since the 1970's, it has become apparent that occupants of many buildings are not satisfied, frequently reporting a high prevalence of health and comfort complaints which they relate to their work environment. This dissatisfaction has adversely effected productivity through higher absenteeism and increased stress. This type of problem is commonly referred to as the "Sick Building Syndrome". This syndrome was first recognized in Scandinavia in the early 1970's, and has subsequently been widely studied in other countries of Western Europe and in North America (1,2). The most commonly reported symptoms include eye, nose and throat irritation, headache, fatigue, nausea, dizziness and skin rash or itchiness. In addition, occupants of sick buildings often report comfort problems such as a lack of fresh air, stuffiness, inadequate temperature control and unpleasant odours.

A large number of investigations of sick buildings have now been conducted by government and private sector organizations. These past building investigations offer design professionals a vast quantity of valuable information about "mistakes" made in the past. Designers can learn how to create "healthy buildings" in the future from the mistakes that have caused "sick buildings" in the past.

A DATABASE OF PROBLEM BUILDINGS

An information system, the Building Performance Database (BPD) has been developed as a tool for building professionals and researchers. The BPD currently contains the results of 366

building investigations conducted by both government agencies (such as NIOSH and Health and Welfare Canada) and private sector organizations. The BPD is an on-line synthesis of a wide range of information collected by the investigators of sick buildings. The database includes bibliographic information about the investigators and their conclusions, architectural and engineering data, and the results of air quality measurements, building system testing and surveys of occupant health and comfort.

BPD is installed on a mainframe computing system in Canada which can be accessed worldwide through existing communications networks. A more complete description of the analytical capabilities of the BPD has been presented elsewhere (3).

PAST "MISTAKES"

The findings from past investigations can provide useful information to design professionals as they plan future buildings. Knowledge about the causes of past occupant complaints can influence design decisions.

Table One summarizes the conclusions from the 366 reports currently contained in the BPD. Review of the data in BPD shows that in many cases, investigators may identify several factors which they feel had all contributed to the building related problems. Consequently, the table summarizes those factors which have been reported by investigators as contributing to building problems. These factors include ventilation related problems, specific indoor pollutants, stress and ergonomic design. Because investigators have frequently indentified more than one cause in a building, the total number of suspected causes in the table does not equal the number of reports in the BPD. This format differs from tables previously developed by NIOSH and Health and Welfare Canada (4,5,6), which have reported one cause per building (i.e. 400 investigations and 400 suspected causes), which may have oversimplified their results. As the objective of this paper is to provide designers with input into future design decisions, the table provides more detail on specific building problems than those of NIOSH and Health and Welfare Canada.

TABLE 1

INVESTIGATOR'S CONCLUSIONS FROM REPORTS CONTAINED IN THE BUILDING PERFORMANCE DATABASE

SUSPECTED CAUSE INDENTIFIED	Number	Percent
VENTILATION CONTROL PROBLEM	159	39.0%
- lack of outside air		
- poor air distribution		
- poor temperature control		
- operational deficiency		
VENTILATION INFILTRATION PROBLEM	40	10.0%
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- refrigerant spill	4	
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STRESS	12	2.9%
ERGONOMIC/WORKSTATION DESIGN	5	1.2%
UNDETERMINED CAUSE	42	10.2%
NO PROBLEM IN BUILDING	35	8.6%
TOTAL	408	100.0%

Ventilation Related Problems

"Ventilation Related" inadequacies are the most commonly reported cause of problems in buildings. A differentiation can be made between problems of "control" and "infiltration".

Ventilation Control Problems. In 39% of the cases contained in BPD, investigators found problems such as inadequate outside air supply, poor air distribution, poor temperature control, a lack of humidification, and various operational deficiencies (such as mechanical failure and poor maintenance practices). All of these causes are "control" problems within the mechanical systems, that

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can often be corrected with fine tuning of the systems. Although not specifically stated in the report conclusions, ventilation control inadequacies probably contribute to other problems in buildings. For example, in those reports where a specific indoor pollutant was cited as the suspected cause, e.g. offgassing of formaldehyde or smoking, the specific pollutant may have been removed from the building if the mechanical systems had been operating effectively.

Ventilation Infiltration Problems. In 10% of the investigations, the cause of building problems was contamination of the outside air supply, resulting from inappropriate location of an outside air intake. Investigators have identified two distinct causes of infiltration problems. First, reentrainment of air exhausted from the building due to the close proximity of air intake and exhaust vents. Second, infiltration from external sources such as automobiles or industry due to improper location of outside air intakes, e.g. at street level on busy downtown streets, adjacent to loading zones or downwind from industrial plants. Designers of future buildings must make certain that outside air intakes are not located such that reentrainment or external infiltration can occur.

Indoor Sources

Specific sources of indoor pollution were cited as the suspected causes of problems in 28.1% of the reports contained in BPD. The specific sources are identified in the table. The most commonly reported sources include offgassing from various building furnishings and finishing materials (20 reports), contamination from print shops, spirit duplicators and blueprint machines (17 reports), and microbial contamination (14 reports). Microbial contamination may partly also be considered "ventilation related", as problems have occurred as a result of the presence of standing water and dampness in HVAC system components. Smoking has been cited as contributory factor to building problems in 12 reports contained in BPD. Other identified sources include pesticides, insulation materials, carpet shampoo and leakage from boilers and water piping.

Stress

In 12 investigations, stress was reported as a contributory factor to the building related problems. In these cases, investigators were unable to determine a physical cause. However,

negative occupant perceptions about the work environment was cited as the main problem. Investigators of problem buildings must take care not to intensify occupant concerns by their presence in the building and "speculation" about building problems prior to final analysis. Recent research has suggested that the presence of investigators in a building may act as a psychological stressor, intensifying occupant belief that problems exist (7). Such problems can be avoided with carefully designed and executed building evaluations. Standardized protocols for building evaluations have been developed by several researchers (8,9).

Ergonomic Design

An important consideration for interior designers is work station design. Although few investigators of sick buildings appear to have considered ergonomic factors, recent research has suggested that VDT work station design is an important factor in occupant comfort for many white collar workers (10). Poor work station design and/or interior layout wes cited as a suspected cause of building problems in five reports contained in BPD.

Unidentified Causes

In 42 cases, investigators were unable to determine the cause of building related problems. All environmental parameters were "normal", and mechanical systems were operating according to established standards.

No Problem in Building

In 35 cases, investigators concluded that there was no problem in the building under investigation, i.e. no health hazard existed. In most of these cases, investigators were asked to evaluate the potential for building related problems, rather than responding to specific complaints.

DISCUSSION

A vast array of information is now available to building design professionals and researchers, which identifies the probable reasons for occupant health and comfort complaints in modern office buildings. This information has been (and will continue to be) synthesized into a database information system, which may be accessed by building designers and engineers.

Review of the findings of the investigations contained in this

database suggest that some of the problems that have plagued many sick buildings could have been avoided at the design stage. This is not to say that designers should be blamed for all sick building problems. A building may have been appropriately designed, but later actions by the building users has created the problem. For example as a result of energy conservation measures, alteration or the building without attention to the mechanical systems, overcrowding, poor upkeep and maintenance, or introduction of specific sources of pollution to the building. Whatever the cause of past problems in sick buildings, tools such as the BPD will be valuable in the efforts to design healthier work environments in the future, in which occupants will be more satisfied with their indoor environment and consequently more productive.

One final word of caution. The creation of healthy buildings is not solely a design issue. Once a building has been properly designed, building operators and users should practice a preventative approach to ensure that the building stays healthy thoughout its life. The design stage should be viewed as the first stage of an ongoing process termed "Building Commissioning", which continues to monitor the functional performance of building through construction and occupancy (11,12).

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Index

THE EPIDEMIOLOGY OF "SICK PUBLIC BUILDINGS"

by THEODOR STERLING and S.KLEVEN

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ABSTRACT

The indoor environment of modern buildings, especially those designed for commercial and administrative uses, constitute a unique ecological niche with its own biochemical environment, fauna and flora. Sophisticated construction methods, new materials and machinery required to maintain the indoor environment of these enclosed structures produce a large number of chemical by-products and permit the growth of many different microorganisms. Because modern office buildings are sealed, the regulation of humidification and temperature of ducted air presents a dilemma, since different species of microorganisms flourish at different combinations of humidity and temperature. If the indoor environment of modern office buildings is not properly maintained, the environment may become toxic to the occupants' health. Such buildings are classified as Sick Buildings. A review of the epidemiology of building illness is presented. The etiology of occupant

illnesses, sources of toxic substances, and possible methods of maintaining a safe indoor environment are described.

INTRODUCTION

Disease has always been strongly associated with the type and use of structures humans occupy. Food, drink, waste products and the presence of any other organic substances (including animals) harbor infectious organisms. With the discoveries of the vectors by which infectious organisms invade a human host have come innovations in building technology and mechanical appliances that cook, store and preserve food, eliminate human waste, and help keep the indoor environment of a building reasonably free of harmful infectious agents. In addition, although not recognized as a source for disease, are toxic chemicals found indoors. The link between the by-products of combustion of biomass materials burned indoors (such as wood, coal, and later on, kerosene and natural gas) and subsequent chronic disease was not recognized until relatively recently. In general, while the type of structure in which people lived and worked may have had a profound influence on their health, specific antecedents of disease were not so much related to a structure of a building as to a specific point source within the structure (e.g., wastes, storage of food, fires used for heating or cooking).

At the start of the twentieth century, a new type of structure became prominent, that of a large public building devoted to commercial or administrative uses. As these buildings grew in size they created a uniquely new environment plagued with problems, primarily because of the great volume of air they enclosed. In addition, the by-products of the machinery required to make these buildings function also created problems. The requirements of air intake, heating, cooling and distribution, and elimination of by-products of human occupation and machinery created needs for massive ducting throughout the full height of the structures, which led to demands for building designs that were large enough to accommodate the machinery necessary to make human occupation possible. (These included the seldom mentioned flush toilets, without which, skyscrapers would be uninhabitable.) However, the main criteria of these early buildings was not so much to eliminate pollutants created inside the building but to prevent infiltration of pollutants from outside. This was especially true for soot from burning coal

used for industrial plants and residences. Initially, attempts were made to regulate the indoor climate by warming and cleaning intake air and then ducting it throughout the building. Outstanding examples of this new technology are the Royal Victoria Hospital in Belfast, built in 1903, and the Larkin Administration Building in Buffalo, New York, built in 1906. From these pioneering efforts came the idea that to condition the indoor environment of a large building and to remove some of the sources of discomforts coming from outdoors, well tempered air must be provided indoors. These initial attempts were further supported by the desire to eliminate the wells for lighting and ventilating the inside of buildings. These wells occupied space that could more profitably be used in commercial buildings for additional office space.

It took the first half of the twentieth century to learn how to supply power to, and maintain these large office buildings. However, starting in the late 1960's, the buildings in the commercial districts of modern cities began to change. New buildings were erected that were sealed structures of great height that relied entirely on mechanical means to regulate their indoor environments. Buildings that used operable windows for ventilation and circulating steam or hot water for heat were replaced by structures with ducted air that was centrally heated or cooled. Advancements in chemistry made possible the manufacturing of entirely new fabrics that were used to cover floors and walls, and construct furniture. Formaldehyde resins were used extensively for particle boards from which furniture or wall panels were constructed and in glues to affix carpets to the floors. A variety of machines were introduced, of which perhaps the most important, from an epidemiological perspective, are the photocopier and certain types of air conditioners. To clean the vast floor areas various carpet shampoos and industrial cleaners were used that sometimes left toxic residues. Filters were used to clean the air circulated by means of the ducting systems. At the same time, however, these filters and duct systems became breeding grounds for various types of organisms (as were some carpets). In short, the modern buildings provided conditions to create a complex ecological niche that became a possible source for human disease.

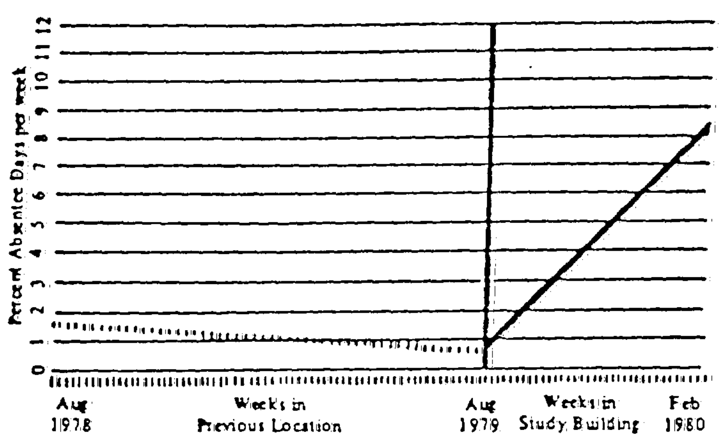
CAUSES OF BUILDING ILLNESS

Since the early 1970's, occupants of hundreds of modern sealed office

buildings throughout North America have reported similar health and comfort complaints (*Berglund, 1984*). These buildings are commonly referred to as "sick buildings" and the epidemic of complaints by the occupants of these buildings has been defined by the World Health Organization as "Sick Building Syndrome" (*WHO*, 1982). Sick buildings are identified by a very high prevalence of specific health symptoms among the occupants which include: headache, eye problems (irritated, sore, dry, itching, or watering eyes), nasal problems (stuffy, runny, or irritated nose), throat problems (dry, sore, or irritated throat), chest problems (chest tightness, difficulty breathing), fatigue and lethargy (including sleepiness and weakness), skin abnormalities (dry, itchy, or irritated skin), and problems maintaining concentration at work (*Sterling, E*, 1983; *Hedge*, 1984; *Finnigan*, 1984; *Robertson*, 1985). In four studies the incidence of "building illness" was found to be at least twice that in naturally ventilated buildings (*Turiel*, 1983; *Hedge*, 1984; *Finnigan*, 1984; *Robertson*, 1985). It has also been suggested that other symptoms, such as skin rashes/irritation/dryness, nausea, dizziness, and respiratory problems (wheeze, shortness of breath, chest tightness) are characteristically more prevalent in sick buildings (*WHO*, 1983; *Stolwijk*, 1974; *Hawkins*, 1985). Finally, there have been complaints in some buildings of increased spontaneous abortions. However, most of these complaints have been anecdotal, and because of the difficulty of counting them, such abortions have not been verified.

The effect of sick buildings on occupant health is demonstrated by the study of *Sterling, E. and Sterling, T.* (1983) of a group of office workers who moved from an old fashioned building with window ventilation and lighting to a modern sealed structure. Absentee data were supplied for a period of one year before and seven months after the study group moved into the new building. The percent of absent days was calculated for all staff members. The study group served as its own control, making possible the comparison of absentee prevalence before and after the move to the new enclosed structure. Figure 1 shows the percentage of days absent for the study group beginning in August 1978 and ending in February 1980. The vertical solid line divides the graph into two parts, before and after the move. There is no trend in absenteeism before the move. Most weekly absences were below 3% and there were no absences at all for 40% of the weeks. The dotted line is the line of best fit resulting from fitting a linear equation to the data for the period of time prior to the move into the study building. The slope of this line is not significantly different from zero. The coefficient of determination

Figure 1. Absentee rate scattergram pre- and post- occupancy of the study building



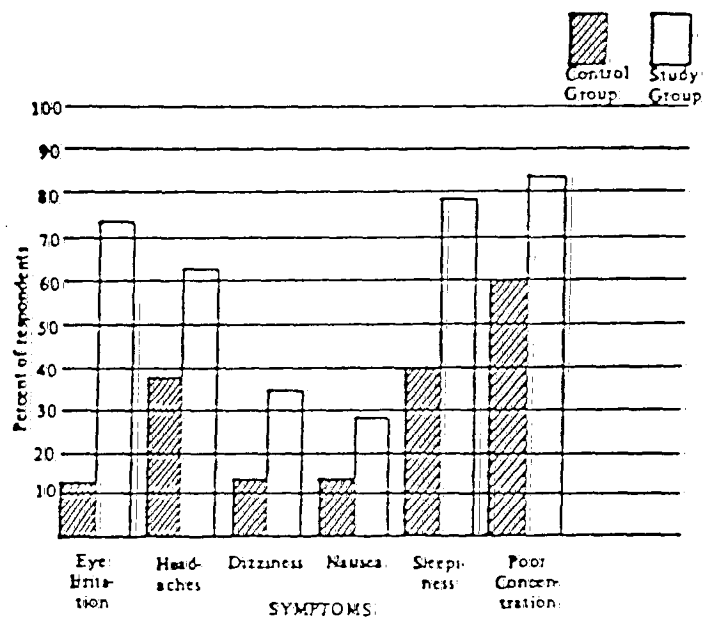
From Sterling and Sterling (1983).

(r^2) between absentee rate and time is 0.03 and the correlation coefficient (r) is -0.17, indicating that no increasing (or significantly decreasing) trend is apparent.

The solid line is the line of best fit of the data for the period of time after the move. The positive slope of 2.66 approximates the linear trend of absentee rates per week in the study building during initial occupancy. The r^2 in this case is 0.53 and r is .73 ($p < .01$). This significant trend clearly shows that absenteeism was increasing after the move into the new building.

Figure 2 details the striking difference in specific complaints in a cross group comparison between a study and control group. The control group oc-

Figure 2 Symptom distribution by group.



From Sterling and Sterling (1983).

cupied a building with operable windows for ventilation and hot water for radiant heat.

SPECIFIC CAUSES OF BUILDING ILLNESS

A number of studies of sick buildings have been able to isolate instances where the cause of health symptoms could be isolated and eliminated by

taking appropriate measures. Such examples contribute important information of how to prevent building wide epidemics.

In 1982 my associates and I started to create an archive of reports of studies of sick buildings (*Collett*, 1987). This archive now contains reports of almost 500 building studies conducted in North America (the majority are located in the U.S). These studies were completed by industrial hygienists and investigators working for the National Institute of Occupational Safety and Health (*NIOSH*) of the United States, the U.S. Center for Disease Control, various municipal and state agencies, universities and other research centers.

Here are some examples identified as contributing causes of building illness:

Formaldehyde: From insulation (*Gunter*, 1981; *Fannick*, 1981) and offgasing from materials containing formaldehyde resins (*Chrostek*, 1981; *Konopinski*, *1980; Coy, 1982)*.

Industrial cleaners: From the residues of industrial carpet shampoos (*Kreis*, 1981; *Robertson*, 1980).

Solvents: From fresh ink on checks in poorly ventilated areas (*Thoburn*, 1981) and printing solvents (*Gunter*, 1981).

Perchloroethylene: From the duct work of a dry cleaner. The gas travelled above the ceiling to other stores in the same complex (*Thoburn*, 1981).

Fiber Glass: Disseminated through the ventilation system (*Kreis*, 1981).

Ozone: (*Shoemaker*, 1977; *Gunter*, 1981).

Automobile exhaust: Entered through the ventilation inlets (*Nudelman*, 1979; *Leiderman*, 1982).

Photocopiers: From a hot oil process, use of methyl alcohol (*Prior*, 1981; *Apol*, 1981; *Fannick*, 1980; *Chrostek*, 1981).

The causes of sick building syndrome are very often unclear. Usually, however, the health symptoms in such buildings can be resolved by increasing the fresh air supply (*Salisbury*, 1981; *McManus*, 1985; *Chio*, 1985).

A summary of what is known about specific causes of sick building syndrome was provided by the U.S. National Center for Occupational Safety and Health (*NIOSH*) in 1984. The findings from 203 of NIOSH's investigations undertaken up to the end of 1983 were reviewed and tabulated by the Health Hazards Evaluation Branch of NIOSH (*Melius*, 1984). Of these 203 studies, 17.7% attributed the health symptoms to indoor air contamination (e.g., from sources such as industrial cleansers or photocopiers), 10.3% to outdoor air contamination (e.g., from misplaced air intake vents that would draw gasoline fumes from garages or bus stations), 3.4% to building contamination (e.g., offgasing of formaldehyde from wall panels, glues and resins in carpets, and furniture made from particle board), 40.3% to inadequate ventilation, 3% to hypersensitivity pneumonitis (often caused by the use of humidifiers), 2% to cigarette smoking, 4.4% to humidity, and 1% to noise and lighting. The remaining 10% of the studies did not find a cause for health symptoms. A review by Health and Welfare Canada (*HWC*) of 94 building studies gave similar results (*Kirkbride*, 1985). In this review, 68% of the studies attributed the cause of health symptoms to inadequate ventilation (e.g., poor air circulation, inadequate fresh air intake, and poor temperature and humidity control) 10% to outdoor contaminants (e.g., motor vehicle exhaust entering the building), 5% to indoor contaminants (e.g., photocopy machines and tobacco smoke; the report does not state to what extent the cause of building illness was due to the use of copy machines or cigarette smoke), 2% to building gases (e.g., formaldehyde, organic glues and adhesives), and the remaining 15% to unknown sources. (Because of present concerns with smoking, all NIOSH and HWC studies paid special attention to smoking as a possible cause of sick buildings. It is of interest, therefore, that smoking was said to be a major cause of complaint only in 2% to 5% of the sick building investigations. Removing the smoker entirely, then, may not affect health and comfort problems in 95% to 98% of sick buildings.)

BIOCHEMICAL SUBSTANCES
IN MODERN BUILDINGS

A wide range of substances have been measured inside modern office buildings. Some of these substances are known, and others are thought to be associated with various diseases. A summary of the measured substances was compiled by the U.S. Environmental Protection Agency and published in the Environment Protection Agency Indoor Air Quality Implementation Plan (1987) under the title "Common Indoor Pollutants, Their Sources and Known Health Effects" (*EPA*, 1987). (Because of its importance, this list is included as an APPENDIX.)

In summary, the EPA table lists 73 common indoor pollutants that are known to be toxic, although not necessarily at the level of concentration found in most buildings. Of these 73 substances, 38 are attributable to building components and appliances, 26 by the evaporation of drinking water, 17 by outdoor air, 16 by products used for cleaning and maintenance, 12 by tobacco smoke, and 9 by vehicles exhaust trapped in garages. Tobacco smoke was singled out by the Environmental Protection Agency because of its visibility. However, with the exception of nicotine and nicotine derivatives, almost all of the substances from tobacco smoke are also derived from a number of other sources. For example, carbon monoxide (CO), besides being present in tobacco smoke, is usually present in much greater quantities, or produced by, HVAC systems, garages, outdoor air and gas stoves; styrine also comes from furnishings and drinking water; benzene from garages and drinking water; methyl chloride from drinking water, pyridine from outdoor air; acetone from cleaners, waxes, adhesives, cosmetics and outdoor air; acroline from the combustion of various products (as are other substances such as formaldehyde or respirable particles); benzo(a)pyrene from automobile exhaust and drinking water; and analine is a by-product from various activities. Sources, other than tobacco, are not given for methylamine and hydrazine. (This may be a result of too few measurements available for these two substances, rather than a real absence of these substances from the combustion of materials other than tobacco.)

In summary, the EPA list demonstrates that there are multiple sources for many chemicals and substances known, or thought, to be toxic. Because

there are so many alternative sources for most substances found in a building, the best method to deal with indoor exposure to biochemicals is to dilute them by adding an adequate amount of fresh air.

THE INDOOR ECOLOGY

A general rule of ecology is that every spot capable of supporting life will be occupied by some form of life. This is just as true for the indoor environment as it is for the Arctic Tundra. Countless substances, necessary to sustain life, are found indoors, especially in the ducts and ventilation system of a building and in all places where moisture may gather. Dusts, much of which contain both the staff of life and microbial and viral life itself, are brought into buildings through fresh air intake and on the clothing, hair and skin of building occupants and visitors. Some of the microorganisms can cause violent physiological reactions in humans.

Perhaps the best known example of the possible virulence of indoor microbial life is Legionnaires' Disease. Legionnaires' Disease, named after an explosive outbreak of pneumonia in a group of Legionnaires attending an American Legion convention in Philadelphia in 1976, is a pneumonia-like reaction to the Legionella Pneumonphilia bacterium. The bacterium requires the presence of certain algae, which usually grow in cooling towers at specific temperatures, for growth (*Fraser*, 1977). Pontiac Fever, named after a health department building in Pontiac, Michigan, U.S., in which the syndrome was first described, is a strain of Legionnaires' Disease (*Kaufman*, 1981). Recurrences of Legionnaires' Disease and Pontiac Fever are documented from time to time, very often in hospitals, and are always connected with poor maintenance of cooling towers (*Friedman*, 1987; *Garbe*, 1985; *Conwell*, 1982; *Kaufmann*, 1981; *Fisher-Hoch*, 1981).

Legionnaires' Disease, however, is just the tip of the iceberg. There are many places in a building in which infectious organisms (bacteria, viruses, fungi, mites) and pollen may flourish. As an example, my associates and I reported allergic and infectious reactions caused by humidifier contaminants (*Arundel*, 1986, see TABLE 1). In general, organic materials will flourish at all levels of relative humidity. Figure 3 describes the relationship between

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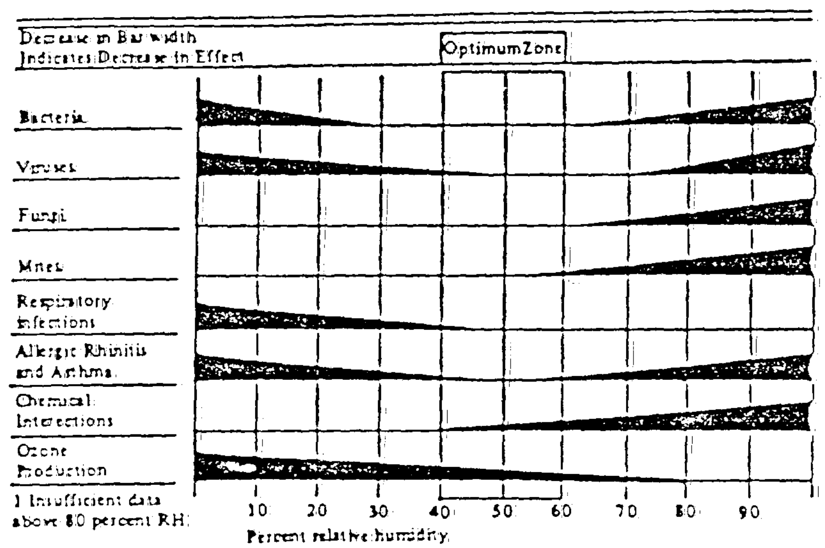
TABLE 1. REPORTS OF ALLERGIES CAUSED BY HUMIDIFIER CONTAMINANTS

Subjects	Diagnosis	Contaminant	Confirmation
11 office workers	Fever, malaise, chest tightness, polyuria	Acanthamoeba spp.	Symptoms disappeared 4 weeks after the humidification system corrected
26 office workers	Fever, chills, cough, dyspnea	Unknown, possibly protozoa	No symptoms 6 months after humidification system removed
24 factory workers	Extrinsic allergic alveolitis	Phialophora spp., Cephalosporium, Fusarium, Gliomastix	Precipitins to humidifier water, symptoms ceased after alteration to system
20 factory workers	Fever, chills, dyspnea	Pseudomonas endotoxins in humidifier	Not stated
3 housewives	Recurrent acute interstitial lung disease	Thermoactinomyces in home humidifier	Positive bronchial challenge to hemophile
1 male	Recurrent pneumonia	Fungi and bacteria in humidifier	Challenge with vaporizer aerosol positive, specific agent unidentified
1 female	Recurrent hypersensitivity pneumonitis	Thermotolerant bacteria in home humidifier	Positive bronchial challenge; positive serum
1 female	Hypersensitivity pneumonitis	Unknown organisms in home humidifier	Positive pulmonary challenge to humidifier water; all family members showed precipitin reactions
1 female	Hypersensitivity pneumonitis	Cephalosporium in home humidifier	Precipitins to antigens
2 asthmatics	Asthmatic episodes	Yeast contaminated aerosols in humidifier	Recurrent symptoms on reexposure
1 female	Pneumonitis, recurrent chills fever, cough, dyspnea	Thermophilic actinomycetes in home humidifier	Positive bronchial challenge
1 male	Hypersensitivity pneumonitis	Thermoactinomyces vulgaris in console home humidifier	Symptoms disappeared when humidifier removed, precipitating antibodies
1 female	Hypersensitivity pneumonitis	Thermoactinomyces vulgaris in humidifier	Precipitins against agent

From Arundel et al. (1986).

Figure 3. Optimum relative humidity range for minimizing adverse health effects.



From Arundel et al (1986).

the humidity and growth of various types of bacteria, viruses, fungi, and mites, respiratory infections, atopic reactions, chemical interactions, and ozone production. As one can see from this figure, the growth of organic materials is minimized if the relative humidity in a building is maintained between 40% and 60%.

CONCLUSION

Modern office and public buildings create an indoor enviror is poorly understood and may be exceedingly hostile to occupants hazards are clearly recognized. Because of the multiplicity of ha the chain of events that lead to physiological reactions in huma taminated indoor environments, no single and/or simple solution(able. Adequate attention to ventilation and fresh air supply will el minimize many of the eye, throat, nose, and/or skin irritations chemicals in the air by diluting them to a safe level. However, inso door air contains a large number of toxic pollutants, it should be a well ventilated building may only be able to maintain outdoo cleanliness.

There are some instances, however, in which modern techn improve and maintain the cleanliness of indoor air as compared air. For instance, adequate filtering systems may remove much o found outdoors and air conditioning and heating systems can for climatic conditions. These technologies, however, need to be app full understanding of the possible effect that application might have health. For example, while filters will remove unwanted dusts and able particles from the outdoor air, such filters also offer a medium for a variety of bacteria and other infectious agents. Therefore, filt ould be changed very frequently, which is a building maintenance expens ilar-ly, aerosols from cooling towers need to be kept away from fresh takes in buildings. This requires careful planning in the placement of se air vents. (In addition, fresh air intake vents should not be placed n street level or garages where they will take in exhaust from motor vehicl and ex-haust vents).

Finally a working relationship needs to be established between build-ing engineers, architects, and epidemiologists. For instance, studying a building with my associate, Elia Sterling (architect), we found that the high absentee rate and prevalence of irritation complaints was caused by the for-mation of indoor smog. A large amount of air was passed over high ultraviolet producing lighting fixtures. The impact of the high level of ultraviolet (UV)

light on the air stream was similar to that of the sun on outdoor pollutants. Ultraviolet light is a cause of outdoor smog in such cities as San Francisco or Los Angeles. Similar UV emissions can cause the formation of smog indoors. We learned from this particular building that air vents should not be constructed to serve as lighting fixtures and high UV sunlight simulating fluorescent lighting should not be used (*Sterling, E. & Sterling, T.* 1983). We also learned that the epidemiology of sick buildings requires a multidisciplinary approach that should include architects, industrial hygienists and ventilation engineers.

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APPENDIX III

INDOOR AIR QUALITY INVESTIGATIONS
MEDICAL SERVICES BRANCH (CANADA)
1984

I. PROBLEM TYPE FOUND

		BUILDING INVESTIGATIONS Number	%
1.	Inadequate Ventilation	64	68
	- Poor Air Circulation		
	- Inadequate Outdoor Air ($CO_2 \geq 800$ PPM)		
	- Poor Temperature/ Humidity Control		
2.	Outdoor Contaminant	5	10
	- Reentry of Building Exhaust		
	- Motor Vehicle Exhaust		
3.	Indoor Contaminant	5	5
	- Copy Machines		
	- Tobacco Smoke		
4.	Building Fabric	2	2
	- Blues and Adhesives		
	- Formaldehyde and Organics		
5.	Biological Contaminants	0	0
6.	No Problem Identified	14	15
	TOTAL	94	100

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Health and Welfare Canada   Santé et Bien-être social Canada

The Occupational Health and Safety
Department of the Human Resources Division
Ottawa Civic Hospital
October 24, 1985

SICK BUILDING SYNDROME:
CAUSES AND EFFECTS

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SICK BUILDING SYNDROME: CAUSES AND EFFECTS

Sick Building Syndrome can be broken down into three sub-categories - Tight Building Syndrome, Humidifier Fever and Legionnaire Disease. TABLE 1.

I will spend most of my time this morning on Tight Building Syndrome.

What is a Tight Building? The definition is arbitrary, practical, and loose. TABLE 2.

There are buildings which meet these criteria in which one can see through gaps between walls and window frames. Paradoxically, some buildings with tight building envelopes - energy efficient residences, for example - do not meet the criteria, since the occupants are able to control the ventilation system.

The health effects that make up Tight Building Syndrome: TABLE 3.

Few researchers would disagree with this list. However, there may be some debate as to whether these are health effects or comfort factors. Is eye irritation an illness? Is headache that clears up on leaving the building an illness? Is fatigue an illness? One can argue either case. The point is not entirely academic, since in real life employees are generally asked to contact health service staff about health problems, and building maintenance staff about comfort problems ...

... /2

You will also note that most of the listed symptoms are rather vague and subjective, and therefore very difficult to measure in a consistent way. Vague and subjective the symptoms may be, yet the syndrome is striking and convincing, and a time-consuming problem to those of us who have responsibilities in the fields of occupational and environmental health. You will also note that a number of these symptoms are attributable to tobacco smoke, a near universal contaminant of office buildings. Until the last few years, tobacco smoke has been looked upon as a normal inoccuous component of indoor air. I will return to tobacco smoke, and some other contaminants, shortly.

Many organizations in many countries have investigated Tight Building Syndrome. The problem was first described in Scandinavia in the early nineteen seventies. By 1975, it was being frequently described in North America.

An American agency that has conducted large numbers of fairly detailed investigations is NIOSH (the National Institute of Occupational Safety and Health). Health and Welfare Canada experience is similar to that of NIOSH. TABLE 4. TABLE 5.

The causes of Tight Building Syndrome TABLE 6.

First, let me mention a non-cause: lack of oxygen. I can say with confidence that the oxygen level in this building and in virtually every office building in Canada

... /3

today is 21%. My organization no longer measures oxygen levels when investigating office buildings with air quality problems.

TABLE 7.

TABLE 8.

TABLE 9.

Pollutants

Let me review some of the pollutants that may be contributory; and let me say in advance that in practice the search for pollutants is usually - not always - unrewarding. With one notable exception: tobacco smoke. Most investigators and researchers will agree that this is the most important single pollutant in the air of office buildings.

Carbon monoxide

Major indoor sources (unvented gas stoves, heaters, etc.) are not usually a problem in office buildings. Motor vehicle emissions can sometimes enter a building - from an attached parking garage, for example.

CO generated by cigarettes would not usually result in indoor levels exceeding industrial standards, although this can occur in small meeting rooms containing numerous smokers.

Formaldehyde

Measured levels in office buildings infrequently exceed the Canadian residential standard of 0.1 ppm. Formaldehyde is a common component of several types of

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condensation-type synthetic resins (e.g. phenol formaldehyde, melamine-formaldehyde, urea formaldehyde.) Urea formaldehyde resin is used in plywood (adhesive) and particle board (binder). Coated paper, floor coverings and fabrics can contains formaldehyde.

Carbon dioxide

Product of combustion and human metabolism. Outdoor levels typically 320 ppm. Office levels typically 600 ppm, depending on quality of ventilation and density of occupants. CO_2 is measured as a proxy of the quality of ventilation.

Ozone

A power oxidizer, and reactive pollutant. The dominant source is the outdoor air, formed by photochemical reaction. Indoor sources are unusual e.g. electrostatic air cleaners, electric motors, photocopiers.

Ventilation factors as a cause of Tight Building Syndrome

From a previous slide (Slide 5), you will remember that in the experience of NIOSH, in about 50% of the buildings investigated, the problems were attributed to faulty ventilation, temperature, and humidity. Let us look at some standards for temperature and humidity:

TABLE 10

These standards may be met for a floor of a building, yet there may still be local problems, created for example by room dividers which restrict airflow.

Temperature and humidity problems are relatively common.

... /5

Psychological factors

These can be very important.

The occupant is aware that he is the best sensor in a building - better able to integrate environmental information than thermometers or hygrometers or airflow meters. Yet he does not have the control over the ventilation system that these instruments may have. The only method left open to him is to express his dissatisfaction to the people who have access to the controls. If these complaints do not produce improvement, the occupant feels out of control, and can become increasingly irritated by these conditions and increasingly sensitive to them. We must also bear in mind that ventilation systems are increasingly complex, and that in a large building only the designer may fully understand them. In other words, maintenance staff may not be in full control of the system.

HUMIDIFIER FEVER

Humidifier fever is an allergic illness. The picture is that of a mild flu' like illness - chills, fever, breathlessness, typically on Mondays on returning to work.

Humidifer fever is a type of extrinsic allergic alveolitis - comparable to farmers lung.

The cause: microorganisms in the humidifying system - bacteria, fungi, protozoa and thermophilic actinomycetes. TABLE 11.

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LEGIONNAIRES DISEASE

You may remember the episode of 1976, at the Bellevue Stratford Hotel in Philadelphia. There were 182 cases of pneumonia-like illness, including 29 deaths, in participants at the annual convention of the American Legion. The diagnosis was elusive. Sabotage, nickel carbonyl poisoning, swine flu, were all suspected, then rejected. Eighteen months later the Centres for Disease Control in the USA isolated and identified Legionella pneumophilia (a bacterium). (The final solution at the Bellevue Stratford hotel was truly final: the hotel was demolished.)

Spread of Legionella in humans: by aerosol from contaminated water systems (e.g. shower heads). Person to person spread has not been described.

How frequent is Legionnaires Disease?

In the USA, in the first four months of 1985, 190 cases were notified. This compares with 102 cases of typhoid, or 982 cases of measles during the same time period.

Other aspects of Legionella are disturbing: TABLE 12.
TABLE 13.

.... /7

LUNG CANCER

This disease is important enough to merit discussion in the context of building associated illness.

When I reviewed some building pollutants, I included radon, asbestos, and secondary cigarette smoke. These agents are all human carcinogens, and can cause lung cancer as well as some other cancers. TABLE 14.

Radon is generally present in much lower levels in office buildings than in residences. Therefore I will not consider it further.

Asbestos is often encountered in building materials, and I would be surprised if this building was an exception. I would also predict that if we were to attempt to measure asbestos in the air of this room it would not be in present in detectable quantities. Asbestos does not present a significant health problem in buildings unless it is damaged, allowing fibres to enter the air.

With regard to secondary tobacco smoke, the evidence from a number of epidemiological studies has been steadily accumulating since 1979. The weight of scientific evidence strongly suggests that secondary tobacco smoke in the workplace is responsible for a significant number of lung cancers - somewhere between 300 and 500 lung cancer deaths per year in Canada.

In conclusion, let me summarize the causes and effects of Sick Building Syndrome: TABLE 15.

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TABLES

SICK BUILDING SYNDROME

1. TIGHT BUILDING SYNDROME

2. HUMIDIFIER FEVER
   (AN INFLUENZA - LIKE ILLNESS)

3. LEGIONNAIRES DISEASE

DEFINITION OF TIGHT BUILDING

LARGE BUILDING

FORCED VENTILATION

OCCUPANTS CANNOT OPEN WINDOWS
OR CONTROL OWN VENTILATION

USUALLY NEW OR NEWLY RENOVATED
BUILDING

HEALTH EFFECTS OF TIGHT BUILDING SYNDROME

EYE IRRITATION

HEADACHE

ODOR

SKIN IRRITATION/RASH

SINUS CONGESTION

COUGH

SORE THROAT

SHORTNESS OF BREATH

ABNORMAL TASTE

DIZZINESS

FATIGUE

NAUSEA

WHEEZING AND HYPERSENSITIVITY

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PRESUMED SOURCE OF THE PROBLEM IN 203 INVESTIGATIONS BY NIOSH

	NUMBER	%
POOR VENTILATION, THERMAL COMFORT, OR HUMIDITY	107	53
CONTAMINANTS FROM INSIDE THE BUILDING (COPIERS, TOBACCO SMOKE, ETC.)	42	21
CONTAMINANTS FROM OUTSIDE THE BUILDING (MOTOR VEHICLE EXHAUST, ETC.)	21	10
BUILDING FABRIC CONTAMINATION (FIBREGLASS, FORMALDEHYDE, GLUES, ETC.)	7	3
BIOLOGICAL CONTAMINATION	7	3
MISCELLANEOUS OR UNDETERMINED	19	10
	203	

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INDOOR AIR QUALITY INVESTIGATIONS
MEDICAL SERVICES BRANCH
1984

PROBLEM TYPE FOUND	BUILDING INVESTIGATIONS	
	NUMBER	%
1. INADEQUATE VENTILATION	64	68
- POOR AIR CIRCULATION		
- INADEQUATE OUTDOOR AIR (CO_2 > 800 PPM)		
- POOR TEMPERATURE/ HUMIDITY CONTROL		
2. OUTDOOR CONTAMINANT	9	10
- REENTRY OF BUILDING EXHAUST		
- MOTOR VEHICLE EXHAUST		
3. INDOOR CONTAMINANT	5	5
- COPY MACHINES		
- TOBACCO SMOKE		
4. BUILDING FABRIC	2	2
- GLUES AND ADHESIVES		
- FORMALDEHYDE AND ORGANICS		
5. BIOLOGICAL CONTAMINANTS	0	0
6. NO PROBLEM IDENTIFIED	14	15
TOTAL:	94	100

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CAUSES OF TIGHT BUILDING SYNDROME

1. POLLUTANTS

2. VENTILATION FACTORS:

   - TEMPERATURE
   - HUMIDITY
   - AIRFLOW

3. PSYCHOLOGICAL FACTORS

POLLUTANTS

CARBON MONOXIDE

TYPICAL OFFICE LEVELS: 0.5 - 5 PPM

INDUSTRIAL STANDARD: 35 - 50 PPM

AMBIENT AIR STANDARD: 9 PPM

FORMALDEHYDE

UFFI RARE IN FEDERAL OFFICE BUILDINGS

MORE IMPORTANT SOURCES:

CARPET BACKING, FABRICS, INSULATION, PARTICLE BOARD;

SMALL AMOUNTS FROM TOBACCO SMOKE

TYPICAL OFFICE LEVELS: LESS THAN 0.1 PPM

RESIDENTIAL STANDARD (CANADA): 0.1 PPM

INDUSTRIAL STANDARD: 1 PPM

RADON

NOT A PROBLEM IN OFFICE BUILDINGS

DOES NOT GIVE RISE TO ACUTE SYMPTOMS

ASBESTOS

NOT USUALLY A PROBLEM UNLESS DAMAGED OR DISTURBED

DOES NOT GIVE RISE TO ACUTE SYMPTOMS

CARBON DIOXIDE

TYPICAL OUTDOOR LEVELS: ABOUT 330 PPM

TYPICAL INDOOR LEVELS: ABOUT 600 - 1000 PPM

INDUSTRIAL STANDARD: 5000 PPM

OZONE

TYPICAL OUTDOOR LEVEL: 0 - 40 PPB

TYPICAL INDOOR LEVEL: 0 - 20 PPB

INDUSTRIAL STANDARD: 100 PPB

VIABLE ORGANISMS (BACTERIA, FUNGAL SPORES, AMOEBAE, PROTOZOA, NEMATODES)

NO STANDARDS

ODORS

STANDARD: ACCEPTABILITY TO PANEL OF OBSERVERS.

NEGATIVE IONS

NO ACCEPTABLE SCIENTIFIC EVIDENCE TO SUGGEST THAT THEY AFFECT COMFORT OR HEALTH.

PHOTOCHEMICAL SMOG

AN INGENIOUS HYPOTHESIS

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MOST FREQUENT OFFENDERS

TOBACCO SMOKE

CARBON MONOXIDE

FORMALDEHYDE

ODORS

VIABLE ORGANISMS?

PUBLIC WORKS CANADA STANDARDS

ACCEPTABLE INDOOR TEMPERATURE RANGE	19°C - 26°C
ACCEPTABLE HUMIDITY RANGE	20% - 60%

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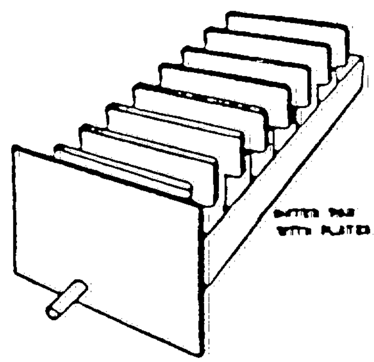
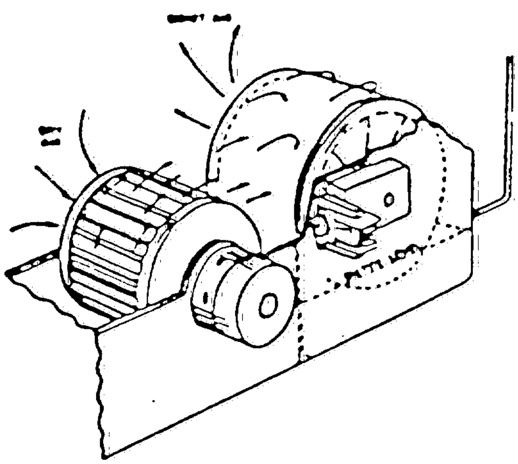
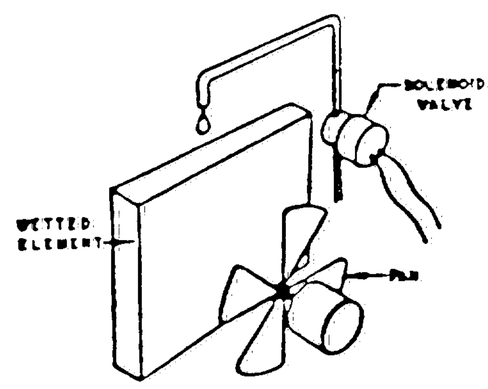
HUMIDIFIERS



Pan-type Humidifier



Wetted Drum-type Humidifier



Power-type Wetted Element Humidifier

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A QUÉBEC CITY HOSPITAL, 1983

12 CASES OF LEGIONNAIRES DISEASE OCCURRED IN HOSPITAL (NOSOCOMIAL INFECTION):

WATER SAMPLES FROM 38 FAUCETS (IN ROOMS):

30% POSITIVE FOR LEGIONELLA

HOT WATER TANKS:

1 OUT OF 2 POSITIVE

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QUÉBEC CITY, 1983

54 DOMESTIC WATER HEATERS WERE EXAMINED

ELECTRIC WATER HEATERS: 11 OUT OF 37 POSITIVE FOR LEGIONELLA

OIL OR GAS WATER HEATERS: 0 OUT OF 17 POSITIVE FOR LEGIONELLA

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LUNG CANCER

~~RADON~~

ASBESTOS

SECONDARY TOBACCO SMOKE

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SICK BUILDING SYNDROME: SUMMARY

EFFECTS

SICK BUILDING SYNDROME ENCOMPASSES: TIGHT BUILDING SYNDROME
HUMIDIFIER FEVER
LEGIONNAIRES DISEASE

CAUSES

POLLUTANTS - CHEMICAL (INCLUDING SOME CARCINOGENS)
- BIOLOGICAL AGENTS

VENTILATION, TEMPERATURE, HUMIDITY PROBLEMS

PSYCHOLOGICAL FACTORS

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APPENDIX IV

ACVA DATABASE (ROBERTSON)

I. ACVA SYSTEMS EXPERIENCE -- 1981 TO 1987. POLLUTANTS

Total building studies	223
Number of square feet	39,000,000
Estimated number of occupants	225,000

Summary of most significant pollutants found:

Major Pollutants in Air	% of Buildings
Allergenic Fungi	34
Allergenic or pathogenic bacteria	9
Glass fiber particles	7
Tobacco smoke	4
Carbon monoxide (vehicles)	3
Miscellaneous gases	2

The fact is that the accumulation of many pollutants is itself a symptom of a more serious problem -- a problem of inadequate ventilation. Medicine teaches us that treating the symptoms simply does not work, one has to go after the cause of the problem.

II. SICK BUILDING SYNDROME CAUSES -- ACVA EXPERIENCE

Sample Buildings:	223
totalling 39,000,000 square feet	
Period:	1981-1987

(1) Poor Ventilation

No fresh air	35%
Inadequate fresh air	64%
Poor distribution of air	46%

(2) Poor Filtration

Low filter efficiency	57%
Poor design	44%
Poor installation	13%

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(3) Contaminated Systems

Excessively dirty ductwork	38%
Condensate trays	63%
Humidifiers	16%

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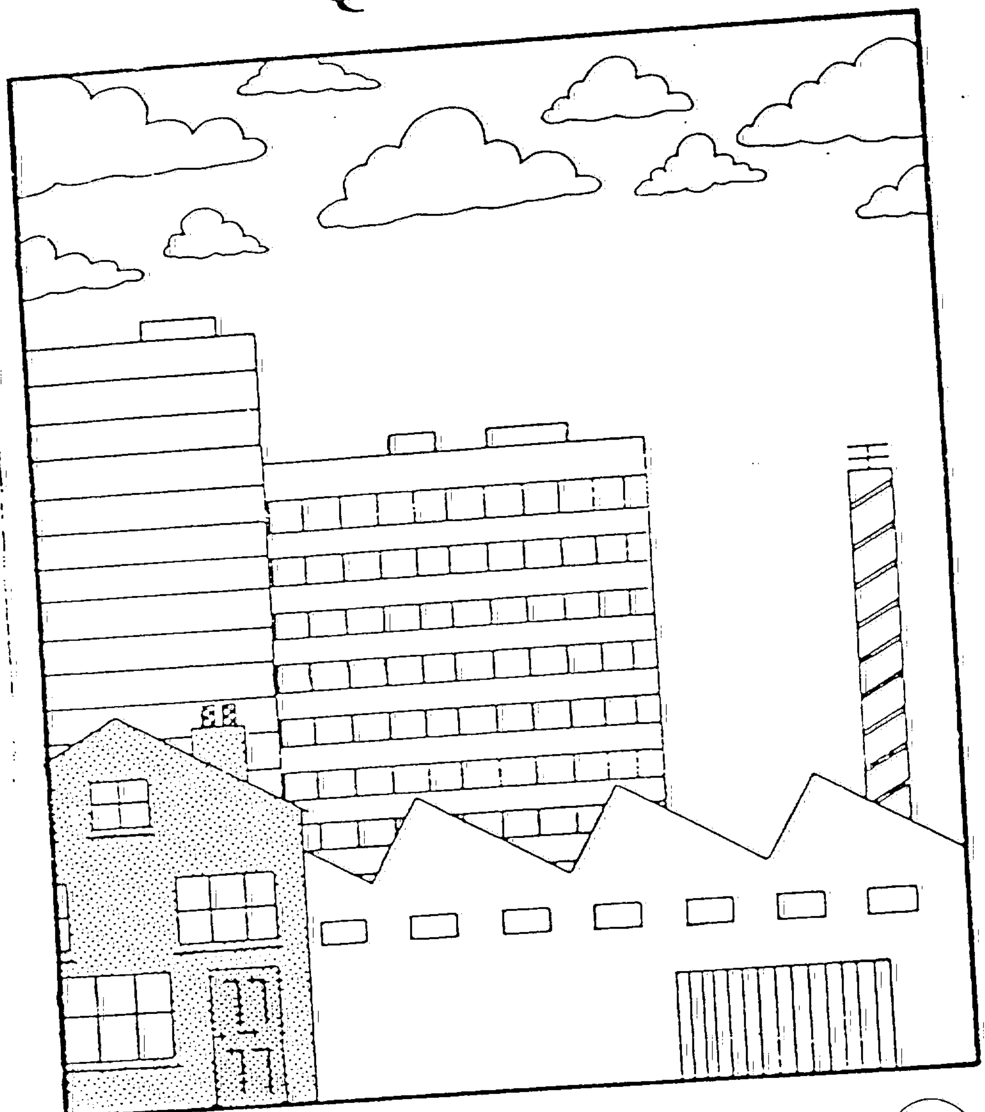
INDOOR AND AMBIENT AIR QUALITY



Edited by R. Perry
and P.W. Kirk

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SOURCE, NATURE AND SYMPTOMOLOGY OF INDOOR AIR POLLUTANTS

G.Robertson

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INTRODUCTION

ACVA Atlantic Inc., specializes in the study of indoor air pollution. Since we established ACVA in 1981, we have pioneered a multi-disciplined approach to the investigation of internal pollution. Investigators include chemists, microbiologists, and air conditioning engineers -- three disciplines unused to working as a team. Our client list includes numerous government agencies; multi-national companies in insurance, finance, industry, banking, and property management; colleges, schools, and numerous hospitals. Most of our clients now not only ask us to examine other buildings that they own, but also enter into long term contracts of regular monitoring and preventive maintenance. In fact, as of March 1988, we have now studied the indoor air quality of over 42 million square feet of property.

INDOOR POLLUTANTS - THE SOURCES

Virtually everything we use in the interior sheds some particulates and/or gases. When a building is new, some compounds are given off quickly and soon disappear. Others continue "off-gassing" at a slow pace for years. Common office supplies and equipment have been found to release dangerous chemicals - especially duplicators and copiers and we have even found formaldehyde being released from bulk paper stores.

People themselves are a major contributor since each person sheds literally millions of particles, primarily skin scales, per minute. Many of these scales carry microbes but fortunately the vast bulk of these microbes are short lived and harmless.

Clothing, furnishings, draperies, carpets, etc. contribute fibers and other fragments. Cleaning processes, sweeping, vacuuming, dusting, etc. normally remove the larger particles, but often increase the airborne concentrations of the smaller particles. Cooking, broiling, grilling, gas and oil burning, smoking, coal and wood fires also generated vast numbers of airborne particulates, vapors, and gases. If the windows and doors are closed all of these can only accumulate in that internal environment.

INDOOR POLLUTANTS -- THE TYPES

There are many types of indoor pollutants, gases, vapors, dusts, fibers, and viable and non-viable microorganisms. Some of the more common ones are described below.

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Organic Chemicals

There are arguably the widest range of pollutants with literally thousands of specific types fortunately occurring in very dilute concentrations which are usually expressed as parts per million or per billion. Most of these are presumed to be safe at the very low levels encountered, although some synergism between different organics or some incidences of organics "sensitizing" people to other pollutants cannot be ruled out. Usually the organics are more a problem in the typical home than the office and concentrations in the home are usually higher than the office mainly due to lower air exchange rates.

Radon Gas

Radon, a decay product of uranium, is present in variable quantities in soils. It moves from the soil by diffusion into the soil's air pockets or into soil water. Then the radon can migrate from the soil air through unvented crawl spaces, building foundation cracks, etc. into the indoor space. Some building aggregates, cinder block, etc. also contain radon and out-gassing from these materials add to the indoor air levels. In other cases radon enters a building via the water supply. Some of this radon is released when there is turbulence of the water such as a running tap. It has been estimated by some researchers that anywhere from 10 to 15% of the average radon we are exposed to comes from such water. However, the general consensus is that the principal source of radon in buildings undoubtedly is the soil gas. Pollution by radon is far more prevalent in homes than in offices, again mainly due to the lower air exchange rates in homes plus the fact that homes have a larger area of exposure to soil relative to building volume and soil leakage area.

Inorganic Oxides

Carbon dioxide is produced by respiration and combustion, oxides of nitrogen and sulphur are combustion products associated with gas stoves, wood, coal fires, and kerosene heaters. Carbon monoxide is emitted from unvented kerosene heaters or wood stoves and it frequently diffuses into buildings from automobile exhaust fumes generated in adjacent garages. Small to trace quantities of each of these gases and other organics are present in cigarette smoke.

Ozone is another gas that is generated, usually in very small quantities, by miscellaneous copying machines and by certain electrostatic precipitators that are used to clean up the air. In one specific case that we studied, the maintenance staff of a building switched off the main air supply fans over the weekend, but omitted to switch off the central electrostatic precipitators. Thus, ozone accumulated inside the air handlers and was subsequently delivered to the staff first thing each Monday morning. When the fans were switched on this caused a severe, though temporary, period of discomfort to the people working in the areas involved.

FIBERS

Asbestos

Prior to 1973, asbestos was the material of choice for fire-proofing, thermal insulation, and sound insulation. It was used as a spray-on insulation of ceilings and steel girders; as a thermal insulation of boilers, pipes, ducts, air conditioning units, etc.; as an abrasion resistant filler in floor tiles, vinyl sheet floor coverings, roofing, and siding shingles; as a flexible, though resistant, joining compound and filler of textured paints and gaskets; as a bulking material with the best wear characteristics for

automobile brake shoes, and in countless domestic appliances such as toasters, broilers, dishwashers, refrigerators, ovens, clothes dryers, electric blankets, hair dryers, etc. In fact, the EPA has estimated that approximately 733,000 or 20% of all government, residential, and private non-residential buildings in the U.S. contain some type of friable asbestos-containing material.

The fact is that many asbestos bearing materials or products are of no health risk whatsoever when used in the normal course of events. However, if for any reason of wear, abrasion, friability, water damage, etc., any of the asbestos fibers are released into the air and inhaled into people's lungs, there is a health hazard. The scientific evaluation of all available human data provides no evidence for a "safe" level of airborne asbestos exposure, thus any quantity should be considered potentially dangerous.

<u>Glass Fibers and Other Man-made Fibers</u>

The glass fiber (usually referred to as fiberglass) industry is in its infancy compared with asbestos and since asbestos related illnesses only manifest themselves tens of years after exposure, there are some schools of thought that suggest glass fiber fragments will also accumulate in the lungs and cause later problems. This may be so, but it is unlikely to be anywhere near as severe. The fibers of glass are not shed in such large quantities as asbestos and most of the resins, etc. bonding the fibers together appear to be extremely effective and long lasting. However, some fragmentation does occur and this is especially noticeable when the loose fiberglass insulation, popularly used in attics and ceiling voids, is disturbed. Most of us have experienced itching on contact with fiberglass and dermatitis-type reactions are not infrequent due to airborne fiberglass particles.

MICROBES

In our reviews of the literature, the one area of indoor pollution that has received least study or research has been contamination due to microbes. Nine percent of the first 223 major buildings studied by ACVA have exhibited high levels of potentially pathogenic or allergy causing bacteria, including Actinomyces and Flavobacterium species. In addition, Legionella pneumophila, the cause of the dreaded Legionnaires' disease has frequently been isolated from inside air conditioning systems.

Perhaps more significantly, we have found over twenty-eight different species of fungus contaminating air handling systems (see Table 1).

Table 1. Fungi Isolated from Air Conditioning Systems by ACVA Systems -- 1981 to 1987

Alternaria sp.	Aspergillus sp.
Aureobasidium sp.	Candida sp.
Cephalosporium sp.	Chaetomium sp.
Chrysosporium sp.	Cladosporium sp.
Curvularia sp.	Diplosporium sp.
Fusarium sp.	Helminthosporium sp.
Monilia sitophila	Monosporium sp.
Mucor sp.	Mycelia sterila
Oospora sp.	Paecilomyces sp.
Penicillium sp.	Phoma sp.
Rhizopus sp.	Rhodotorula sp.
Saccharomyces sp.	Scopulariopsis sp.
Streptomyces sp.	Tricothecium sp.
Verticillium sp.	Yeasts

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Of the 223 buildings studied by ACVA between 1981 and 1987, thirty-four percent have been found to contain high levels of potentially pathogenic or allergy causing fungi, including Alternaria, Aspergillus, Cladosporium, Fusarium, and Penicillium species. In many buildings with excessive staff complaints, either Aspergillus and/or Cladosporium species of fungus were found growing to excess in the air conditioning ductwork systems. In some investigations, epidemiological tests run by various doctors have confirmed severe allergic reactions to the spores of these fungi in all affected staff. Subsequent cleaning and removal of the sources of these fungal contaminants have resulted in a complete abatement of complaints.

DIRT IN DUCTWORK

HVAC systems also have been found to be poorly designed and negligently maintained. Excessive dirt accumulations are common in ductwork, even in hospitals. Frequently dirt is built into the systems during construction since the ducts are installed long before the windows, etc. and construction dusts from the site, plus wood shavings, lunch packets, coke and beer cans, etc. find themselves brushed into the vents then "out of sight -- out of mind." Thereafter over the life of the building, more dirt enters with the supply and return air. Good filters reduce the rate of this accumulation, but the only perfect filter would be a brick wall. All filters, even the ultra-efficient HEPA filters used in hospital operating rooms allow fine particles through. Many of these fine particles coalesce, sticking to each other by adhesion or electrostatic attraction and larger particles simply grow with time. In commercial buildings, much cheaper and far less efficient filters are common. Many will stop birds and moths, but that is about all. Occasionally we find that the filters have been omitted and very frequently we find they are undersize, resulting in large air gaps that allow massive volumes of air bypass to occur. Then, there are the large electrostatic precipitators that theoretically provide ultra-efficient air. In one major building we found 16 out of their 18 precipitators were inoperative due to broken parts, many had not worked for over a year. In a major hospital, we found the power pack was missing from one of these units. When inoperative electrostatic precipitators provide zero filtration.

Dirty ductwork is a prefect breeding ground for germs. It provides an enclosed space, constant temperature, humidity, and food -- which is the dirt. No germ could wish for more!

The extent of this potential problem is huge and it is very surprising what we have found in ducts. Dead insects, molds, fungi, dead birds and rodents are common. In 1984 we found two dead snakes in air supply ducts. We have also found rotting food, builders rubble, rags, and newspapers. All of these contaminate the air we breathe. It is the dirt that encourages germs to breed -- germs which cause infections.

The dirt and dusts also may be allergenic, in fact most of the dusts are, by definition, household dusts which are notorious for causing allergies in many people.

In a survey of a 750,000 square foot hospital in Virginia, we found 14 miles of ductwork. Here are a few examples of the problems we encountered in that maze of ducts. Smoke detectors blocked by dirt and inoperative; fire dampers jammed open by dirt -- they were unable to close; reheat coils completely blocked by dirt sealing off the fresh air supply; turning vanes and even the exhaust grilles completely sealed with dirt accumulations -- in the operating suite the exhaust fan was still working against these duct blockages causing such immense negative pressure in the ducts that the ducts were bowing inward almost to the point of collapse; huge excesses of bacteria and fungi were present inside the air handling chambers and throughout the ductwork; cross infection rates were high and nurses, doctors, and patients complained

about poor air quality. We have since cleaned all the air handlers and the 14 miles of ducts and have overseen the installation of more efficient filter systems. That hospital has been dramatically improved and its air quality is now well above average.

SYMPTOMOLOGY OF INDOOR AIR POLLUTANTS

In general, when one hears of a polluted building or a so-called "sick building," one hears familiar symptoms from occupants including eye and nose irritation, fatigue, coughing, rhinitis, nausea, headaches, sore throats, and general respiratory problems. Without doubt, the pollutant most often blamed for these symptoms by the public is environmental tobacco smoke (ETS). However, there are usually confounding variables presented by a number of potential contaminants that precludes a quick analysis establishing a single source of contamination. The main problem being the incredible similarity between symptoms from widely different irritants or even environmental conditions. For example, identical symptoms have been reported for individuals exposed to formaldehyde, ammonia, oxides of nitrogen, and ozone. In addition, similar symptoms are reported by those individuals suffering allergic type reactions to numerous dusts and to microbial spores such as Aspergillus, Penicillium, and Cladosporium fungi, among others. Similar symptoms have been reported from exposure to cotton dust and fiberglass fragments and an ever increasing and similar problem is encountered due to low relative humidities. The latter is well known to frequent flyers of airliners where relative humidity levels are frequently as low as 10%, compared to a normal lower comfort level of say 40%.

This similarity of symptoms is usually unappreciated by the public and in part it accounts for a bias against tobacco smoke, which happens to be the sole visible air pollutant. Furthermore, due to their unreliability, we, as a policy, refuse to rely upon or otherwise use the information generated by subjective building occupant questionnaires. Only upon careful investigation of the entire indoor environment and ventilation system of a building can be draw informed conclusions about the various causes of poor indoor air quality. As a result, we have made it our business to perform precisely such investigations. Despite being the main suspect of the occupants in many of the buildings we have examined, we have determined high levels of environmental tobacco smoke to be immediate cause of indoor air problems in only four percent of the 223 major buildings investigated by ACVA between 1981 and 1987 (see Table 2). Significantly, in those few cases where high accumulations of ETS have been found, ACVA also has discovered an excess of fungi and bacteria in the HVAC system. These microorganisms usually are found to be the primary causes of the complaints and acute adverse health effects reported by building occupants.

Table 2. ACVA Systems Experience -- 1981 to 1987.

Total building studies	223
Number of square feet	39,000,000
Estimated number of occupants	225,000

Summary of most significant pollutants found:

Major Pollutants in Air	% of Buildings
Allergenic Fungi	34
Allergenic or pathogenic bacteria	9
Glass fiber particles	7
Tobacco smoke	4
Carbon monoxide (vehicles)	3
Miscellaneous gases	2

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Miscellaneous gases	2

VENTILATION AND INDOOR POLLUTION

The fact is that the accumulation of many pollutants is itself a symptom of a more serious problem -- a problem of inadequate ventilation. Medicine teaches us that treating the symptoms simply does not work, one has to go after the cause of the problem.

Improper ventilation can sometimes be carried to extremes. The fresh air dampers were closed completely in over 35% of those buildings studied by ACVA (see Table 3). Three years ago we found a building where the "maintenance engineer" had bricked up the fresh air vents to save energy. In Washington State, one NIOSH investigator of a sick building found heavy duty polyethylene

Table 3. Sick Building Syndrome Causes -- ACVA Experience

Sample Buildings:		223
totalling 39,000,000 square feet		
Period:		1981-1987
(1)	Poor Ventilation	
	No fresh air	35%
	Inadequate fresh air	64%
	Poor distribution of air	46%
(2)	Poor Filtration	
	Low filter efficiency	57%
	Poor design	44%
	Poor installation	13%
(3)	Contaminated Systems	
	Excessively dirty ductwork	38%
	Condensate trays	63%
	Humidifiers	16%

sheets sealing off the fresh air intakes. It turned out that these had been installed two years earlier to reduce the levels of silica dust being carried into the building from Mount St. Helens. There are also numerous incidences of inadequate ventilation due to hidden blockages inside ducts. Using fiber-optic technology, we have found many classical examples of such where turning vanes, dampers, and reheat coils inside ducts have been totally sealed with massive accumulations of dirt, loose insulation, etc.

Perhaps the most serious problem of ventilation is that there is no effective legislation mandating the uniform use of minimum fresh air requirements. Certainly some authorities do specify ventilation rates at the design stage -- most of these are based on ASHRAE or BOCA standards. However, the major problem is that there is no legislative structure, nor is there a practical policing methodology to ensure that the operators of buildings run their ventilation systems according to such designs.

THE EFFECT OF ENERGY CONSERVATION

Some of these examples of inadequate ventilation were due to ignorance or accidents, however, the complex of symptoms that I have mentioned -- the "sick building syndrome" -- may result primarily from energy conservation efforts to seal buildings and reduce the infiltration/exfiltration of air. Such efforts have reduced the natural infiltration of fresh air that previously existed in many buildings, exacerbating the often undiscovered problem of a poorly designed or maintained HVAC system.

In addition to tightening buildings and sealing windows, building managers have shut down air conditioning systems at night and on weekends in an effort to lower energy costs. When the air conditioning is shut down in humid climates, condensation builds up and settles inside the ductwork. If dirt is present in damp ductwork, spores and microbes can flourish, only to be spread throughout the building once the HVAC system is turned on the next morning. This often results in Monday morning complaints of building odors or building sickness that disappear during the week, only to recur the following Monday morning. To save more energy, automatic temperature controllers are used to cycle fans on and off during the day. Vibrations from the start-up of these fans can cause dirt and microbes trapped inside ductwork to be dislodged and carried into occupied areas.

Another energy conservation effort that may contribute to sick building syndrome is the recirculation of indoor air, at the expense of fresh outdoor air. The 35% of the buildings mentioned above were saving energy by shutting off all the fresh air.

Extremely bad distribution of air throughout the building is common, especially in those systems using multiples of fan coil units mounted throughout the various floors of the building. Local thermostats switch off individual units independently of others and micro-environments are set up. Often it is necessary to ensure that when the heating or cooling is not required, all the fans should be left running to aid circulation throughout the areas concerned.

Variable air volume systems (VAV) using VAV mixing boxes mounted in the ceiling void frequently have louvers opening into the void. When certain temperature conditions are met, the louvers open and return or exhaust air from the void can be induced into the supply air, bypassing the filtration system. We have found fiberglass, asbestos, fungi, and ETS to be recycled throughout an office due to this design.

More and more frequently one finds the following design condition, exhaust fans rated at say 70 to 80% of the supply fans. The supply fans are often automatically throttled back for energy savings, say to 25% of their rated capacity. If the exhaust fan is not adjusted at the same rate the exhaust fan can overpower the supply fan and no fresh air gets into the building. The open fresh air louvers now act as addition exhausts and the whole building runs at negative pressure. When this occurs, unfiltered outside air infiltrates into the building or, worse still, exhaust fumes are sucked up from underground garages.

In addition, as described above, the substitution of low cost, low efficiency filters to reduce pressure drops and save energy seriously reduces the efficiency of building filtration systems, and can lead to serious indoor air quality problems.

VENTILATION COSTS

Without doubt, the major resistance to increasing ventilation rates has been the cost of such increases. Most companies have incorporated energy management problems and new operating budgets based on saving every energy dollar possible. In fact, the very salaries and bonuses of building engineers or energy managers are dependent on reduced costs. It would be an anathema for them to consider increasing energy usage and cost by increasing ventilation.

However, forward thinking companies should look way beyond the constraints of budgets of the energy managers. Consider the following: the average heating, ventilation, and air conditioning operating costs of a typical 100,000 square foot building in the Washington, D.C. area would be $50,000 per annum. A commendable target for energy saving by saving on ventilation may be say 25% savings, giving a useful $12,500 per annum. Of course, many of you present

operate buildings many fold larger than 100,000 square feet, so these savings are an attractive goal (see Table 4).

Table 4. Energy Conservation.

Consider a 100,000 square foot building
Typical total utilities cost ($1.25 and $1.75/sq ft)
Average: $1.50/square foot - $150,000 per annum

Typical HVAC fraction (25% to 40%)
Average: 33% - $50,000 per annum

Thus: All energy conservation steps by
reducing ventilation, increasing air
recirculation, etc. contribute a
fraction of $50,000 per 100,000 square foot
Note: a 25% energy savings - $12,500 per year

Now, consider the payroll costs for people in that building. Using typical averages, there are 150 square feet of space per employee, therefore each 100,000 square feet would house 667 people. Supposing we paid these staff only $15,000 per annum for the salary plus payroll costs, the salary bill (667 x $15,000) would be approximately $10,000,000 per annum per 100,000 square feet. Thus, each 1% absenteeism costs $100,000 per annum (see Table 5). Typical absentee rates run at 3 to 7% and no less than 30 to 50% of all absenteeism is estimated to be due to upper respiratory problems. How many of these are due to dusts, bacteria, fungi, fibers, chemicals, ETS, carbon monoxide, oxides of nitrogen, etc., i.e., how many are due to these internal pollutants.

Table 5. Payroll Costs.

Consider 100,000 square feet
Average staffing - 150 square foot/employee
$\frac{100,000}{150}$ square feet - 667 employees

Assume average salary and benefits - $15,000 per annum
667 x $15,000 - $10,000,000 per annum
i.e., each 1% absenteeism costs $100,000 per annum

Note on Averages: Upper respiratory complaints -
30 - 50% of all absenteeism

In short, what does it profit a company to save $12,500 in energy savings if that small saving causes potentially hundreds of thousands of dollars in absenteeism, not to mention lost worker efficiency. Small wonder that some European countries, including Denmark, West Germany, and Switzerland have introduced legislation mandating that steps must be taken to prevent the buildup of internal pollutants. The United States is destined to follow that course either by slow evolution or legislation will be precipitated as a result of court actions brought by individuals or by trade unions making the building owners, architects, designers, and operators responsible for the health and welfare of their staff or tenants.

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AN INDOOR AIR QUALITY SURVEY OF TWENTY-SIX SWISS OFFICE BUILDINGS

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In an effort to characterize the major factors influencing air quality in buildings in Switzerland, 26 representative buildings were selected for this study. Each building was subjected to the same indoor air quality survey methodology. The most significant cause of air quality problems was found to be poor ventilation, followed by inadequate filtration and poor hygiene. Control of Legionella bacteria and asbestos-containing materials may also require high priority in order to prevent immediate and long term hazards to building occupants.

INTRODUCTION

There is a continuing requirement for air quality data on buildings not classified as "sick" which are representative of buildings as a whole within a specific region or country. Currently, data on levels of many common indoor pollutants in Switzerland are sparse. In addition, it has been shown in the U.S. (1,2,3) that maintenance activities and the condition of air handling equipment can have a profound affect on indoor air quality. Information on these factors in Switzerland is equally hard to find.

This survey selected and evaluated a representative group of 26 commercial office buildings comprising a total of approximately 102,300 square meters of office space in 20 cities in Switzerland. The objective of this survey was to provide contributory data for future mitigation policies, as well as to help set guidelines for suitable ventilation rates and filtration standards in particular. These studies were carried out from the 7th of February to the 15th of March 1989. The buildings selected for this survey were of a wide variety in terms of their size, construction and use. However, a standard methodology to investigate each building was applied.

METHODOLOGY

Although a standard approach was used to survey each building, it required flexibility to cope with different types of buildings examined.

Initial Walk Through

Since one of the objectives of this survey was to assess maintenance standards, each study commenced with an interview with the personnel responsible for maintenance of the building. Questions were designed to elicit operative details such as system on/off times; fresh air, return air and exhaust settings; scheduled maintenance routines; and complaint areas, if any, but did not include questioning of the occupants. There was a walk through of each building to

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identify obvious building configurations or design features which could influence air quality in the occupied areas. This was followed by a complete visual inspection of the internals of the building's ventilation system, if any. A visual inspection was also made of the internals of the main air supply ductwork leaving each air handling unit. Where necessary, access was gained to this ductwork by the installation of a small access port and the insertion of a fiber optic borescope.

Qualitative Sampling

In each air handling unit and main air supply duct, a series of samples were also collected on cellulose ester filters for light microscopy analysis. Surface microbe samples were collected on Random Organism Detection and Counting (RODAC) agar plates, to be subsequently incubated, counted, and identified.

A laser particle counter with a size-selective inlet for sampling particles with an aerodynamic diameter of 0.5 microns and above, was used to count particles inside the ductwork. At least two points were sampled inside each major run of ductwork. This qualitative information on the building, along with the location of the samples and the building engineer questionnaire, was prepared on a set of standard field notes to ensure consistency. In the case of buildings not equipped with forced air ventilation systems, this walk through and sampling phase was obviously more limited in scope.

Quantitative Air Sampling

A set of locations were identified in each building to be used for quantitative airborne sampling. These locations were spread evenly throughout the study area of each building with a minimum of two locations per floor, as well as an outdoor control sample point. The following parameters were measured at each location where relevant and appropriate:

- Respirable airborne particle counts, using a piezoelectric microbalance;
- Carbon dioxide levels, using a non-dispersive infrared absorption portable gas analyzer;
- Carbon monoxide concentrations, using a controlled potential electrolysis detector;
- Airborne nicotine (after Ogden et al (4)), with a personal universal flow sampling pump;
- Temperature, using a miniature platinum Pt 100 resistance sensor; and
- Relative humidity, using a chromed layered capacitative electrode.

The following parameters were measured in at least two selected locations in each building:

- Miscellaneous gases, using Gastec calibrated detector tubes.
- Airborne microbial counts, using a centrifugal air sampler employing impaction onto an agar lined drum;
- Formaldehyde, using midget impingers containing sodium bisulphite, followed by spectrophotometric analysis;
- Radon gas in basement areas, using Track-Etch radon detectors;
- A range of volatile organic compounds, using a GC/MS in one or two locations per building, plus an outside control for each city;
- Bulk asbestos analysis of any materials in the air stream of the ventilation system, or exposed to the building occupants, which were suspected of containing asbestos fibers;
- Sampling and counting of airborne asbestos fibers;
- Sampling of selected water sources, and analysis for the presence of *Legionella pneumophila*, along with a hazard assessment of the water source for possible future contamination and dissemination of this organism.

RESULTS AND DISCUSSION

This survey yielded a large amount of data which can be broadly classified as either quantitative analytical data or more empirical assessments of the condition of the air handling systems. The quantitative data is shown in Tables I, II and III, with the qualitative data assessed and ranked on Figure 1.

Nitrogen dioxide, lower and higher range hydrocarbons, ozone, ammonia, and sulphur dioxide were not found above the detection limit of the method used and are, therefore, not included in these tables.

TABLE I. MECHANICALLY VENTILATED AREAS

Building	CO_2 (ppm)		CO (ppm)		RSP (μgm^{-3})		Total HCHO	VOCs	Nicotine	Radon	Airborne microbes
Area	am	pm	am	pm	am	pm	(ppm)	(μgm^{-3})	(μgm^{-3})	(Bqm^{-3})	($cfu\,m^{-3}$)
A (all)	628	545	4.3	4.1	41	35	0.03	1161	6.6	--	238
C (all)	408	408	2.5	2.7	53	53	0.01	64	<DL	40	340
F (all)	454	587	3.6	3.7	13	19	0.01	2030	4.0	18	111
I (all)	496	442	4.3	4.4	29	35	0.04	515	2.9	29	170
R (all)	528	492	2.5	0.8	20	28	<DL	--	--	33	374
Y (all)	473	491	3.5	3.3	14	12	0.02	276	3.5	81	600
Z (basement)	500	600	3.0	2.5	15	10	0.03	772	--	66	1000
MEAN	498	509	3.4	3.1	26	27	0.02	900	3.4	44	405

TABLE II. NATURALLY VENTILATED AREAS

Building	CO_2 (ppm)		CO (ppm)		RSP (μgm^{-3})		HCHO	Total VOCs	Nicotine	Radon	Airborne microbes
Area	am	pm	am	pm	am	pm	(ppm)	(μgm^{-3})	(μgm^{-3})	(Bqm^{-3})	($cfu\,m^{-3}$)
D (B-2F and 5F-8F	523	564	2.4	3.4	21	36	0.06	--	--	77	334
E (all but lab	600	622	2.7	6.7	92	56	0.06	824	<DL	62	768
G (all but reception	858	642	6.2	4.2	118	357	0.06	991	23.4	37	775
H (all but computer/conference rooms)	669	572	2.1	3.5	14	16	0.12	2693	3.9	44	116
J (all)	679	871	3.4	3.6	29	34	0.20	1206	41.9	29	533
K (all)	817	817	1.5	11.8	98	87	0.04	2859	18.3	48	268
L (all)	938	588	2.5	2.0	31	14	0.07	2033	2.8	59	157
M (total study area)	733	544	2.0	2.0	49	30	0.01	562	17.8	23	366
N (all)	746	750	2.0	2.0	16	16	0.02	414	15.1	275	254
O (complete study area except 3F conf, lounge, and 2F lounge)	692	713	3.3	2.4	33	--	0.02	935	--	29	273
P (all)	670	895	2.4	2.0	25	33	0.02	702	<DL	37	171
T (all)	731	613	2.5	2.0	32	24	0.03	146	9.0	209	156
U (Ground floor offices, basement)	600	475	3.0	2.5	100	85	0.04	--	--	37	500
V (all)	683	692	3.5	2.5	33	15	0.04	84	5.3	92	325
W (all)	556	600	2.7	2.6	46	52	0.02	910	<DL	532	372
X (all)	900	720	2.4	2.4	144	78	0.03	138	<DL	14,641	38
Z (all but basement)	575	658	2.3	2.3	45	78	0.02	--	3.0	--	454
MEAN	704	667	2.8	2.8	55	63	0.05	1036	10.0	106*	345

*This mean figure does not include the result from Building X.

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TABLE III. MIXED VENTILATED AREAS

Building Area	CO_2 (ppm) am	CO_2 (ppm) pm	CO (ppm) am	CO (ppm) pm	RSP (μgm^{-3}) am	RSP (μgm^{-3}) pm	HCHO (ppm)	Total VOCs (μgm^{-3})	Nicotine (μgm^{-3})	Radon (Bqm^{-3})	Airborne microbes ($cfum^{-3}$)
B (all)	579	561	5.4	4.6	19	16	0.04	2420	25.7	37	377
D (3F-4F)	460	450	3.0	3.4	12	14	0.01	1366	<DL	--	271
E (CF lab)	1250	1850	3.0	3.0	80	130	--	599	--	--	259
G (CF reception	350	400	3.0	2.0	40	80	--	--	<DL	--	775
H (computer/ conference)	550	700	2.0	4.0	20	10	--	--	--	--	13
O (3F conf. lounge and 2F lounge)	508	617	3.3	2.7	25	--	--	--	2.7	--	516
Q (all)	620	573	2.4	2.7	55	13	0.03	329	2.1	33	533
S (all)	750	517	3.2	2.8	43	42	0.03	321	1.4	77	554
U (1F, 3F, CF cafe)	550	558	2.7	2.8	70	57	--	1070	1.1	--	481
MEAN	624	692	3.1	3.1	40	46	0.03	1018	4.7	48	420

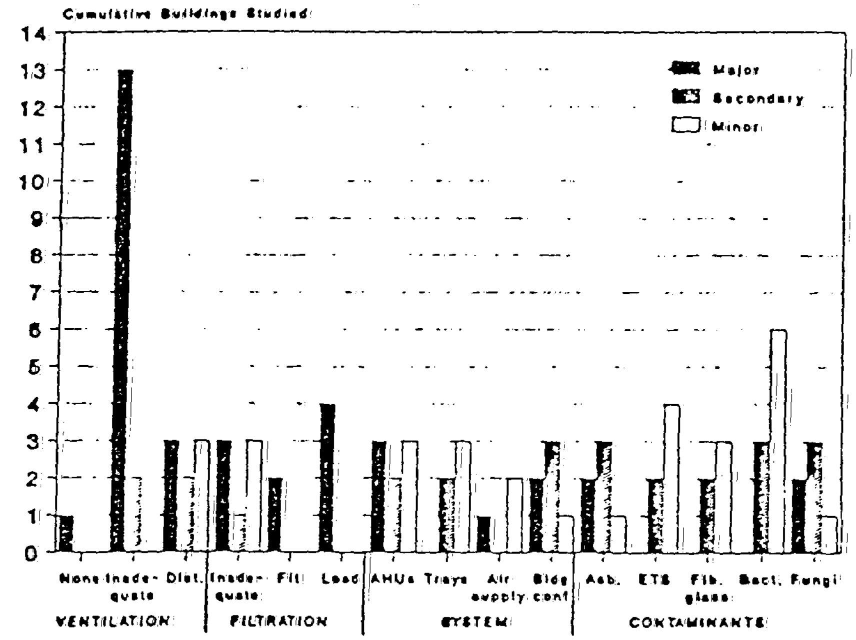
CO	carbon monoxide	CO_2	carbon dioxide
RSP	respirable size particles	HCHO	formaldehyde
VOCs	volatile organic compounds	μgm^{-3}	microgram/cubic meter
ppm	parts per million	DL	detection limit
--	not tested for	Bqm^{-3}	Becquerels/cubic meter
$cfum^{-3}$	colony forming units/cubic meter		

These 26 buildings varied widely, and as a result, there were many items found which were unique to a particular building. Specific problems included HVAC outside air intakes directly adjacent to parking lots. This type of problem is reflected in the "building configuration" section of Figure 1. Another problem unique to a building was an excessively high radon concentration in an area of Building X which required immediate attention. There were, however, some other more pervasive factors which were common to at least a sub-set of the buildings.

Since this survey was made in winter, most operable windows remained closed. As a result, many of the buildings that were not equipped with forced ventilation systems became somewhat stuffy, and this was reflected in elevated carbon dioxide concentrations, either throughout the building, or in certain pockets. Table III shows carbon dioxide levels overall in the naturally ventilated buildings to be slightly lower in the afternoon -- this coincides with observations that windows were more often open in the warmer afternoon hours than in the colder mornings. Table III also shows that most indoor pollutants measured were marginally higher in the naturally ventilated areas. An exception is carbon monoxide, which was generally lower and this may be due to the presence of underground parking garages under many of the sealed, mechanically ventilated buildings.

Low ventilation rates can be seen to affect more than half of these 26 buildings (Figure 1) and may be indicative of a general trend. Since the majority of underventilated buildings were older structures with little or no mechanical ventilation system, it demonstrates that indoor air quality problems are not limited to U.S. style "high tech" sealed buildings, but are just as likely in older buildings (at least in seasons of adverse weather).

Figure 1. Indoor Air Quality Problems from 26 Swiss Buildings



None - no fresh air
Inadequate - limited fresh air
Dist. - poor fresh air distribution
AHUs - dirty air handling units
Trays - blocked or dirty condensate trays
Air supply - dirty air supply ducts
Bldg Conf - building design or configuration problems

Inadequate - low efficiency filters
Fit - poor fitting filter
Load - excessively dirty filters
Asb. - presence of asbestos
ETS - environmental tobacco smoke
Fib. glass - loose in air supply system
Bacteria - presence of infectious or allergenic bacteria
Fungi - presence of infectious or allergeni fungi

Overall, dust levels were higher in the naturally ventilated buildings not equipped with a filtration system. This is not surprising since dusts generated by occupant activities are more likely to be suspended in the room air for long periods instead of being drawn into a return system. In the more sophisticated buildings, a number of filter systems were found to be subjected to poor maintenance -- most commonly the selection of filters which are likely to rate less than 10% efficient in the respirable size range. Most commercial systems should be fitted with filters at least 20% efficient in this size range. A minority of these filters were poorly fitted, allowing air bypass, and four buildings were found to have filters which were excessively loaded. We still require a standard test which evaluates the ability of the filter to remove sub-micron size particles since these are the ones that penetrate deep into the respiratory system. We currently do not have such a test which is applied routinely to commercially available filters.

Due to poor maintenance, heavy dirt created problems in most of the air handling units inspected. Condensate trays and air supply ducts were also found to be

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loaded with various levels of dirt, slime or scale. Sampling for *Legionella pneumophila* in building water using the Legionella Rapid Assay method, revealed trace levels of the organism in five buildings, and strongly positive results in three buildings. These made up the majority of the bacterial problems found in this survey and demonstrate that this organism may be quite widespread in cooling and humidifying systems in Swiss buildings. In all twenty-six buildings, airborne microbial samples yielded wide ranges of fungal species. These were generally similar to outdoor air sample results. Better attention to hygiene of air handling systems may be one of the more effective ways of reducing occupant exposure to irritants in many Swiss buildings.

A minority of buildings exhibited poor use of fibrous glass, creating the potential for release of fibers either into the air stream of the ventilation systems, or directly into the room air. This is a maintenance item which is relatively simple to correct. More complex problems are raised by asbestos containing materials which were found to be a significant problem in two of the buildings examined, and secondary or minor problems in a further four. The control of fiber release from asbestos containing products in Swiss buildings may be a topic which requires significant educational effort in the future.

Environmental tobacco smoke was found to be a secondary or a minor irritant in a total of six of these buildings, usually associated with pockets of poor ventilation. Ventilation rates which maintained carbon dioxide levels consistently below 800 ppm, resulted in low levels of ETS, both as measured by nicotine and RSP levels.

The most room for improvement in these buildings was found with ventilation rates, which were inconsistent, and, in mechanically ventilated buildings, with overall levels of maintenance, especially with regard to filters and cleaning schedules. In particular, there is a need for a standard filter testing method for respirable dust removal. Furthermore, if these buildings are representative of many Swiss buildings, control of *Legionella* bacterium in cooling systems, improvement of hygiene of air handling units to maintain low levels of bacteria and fungi, and abatement of asbestos containing materials in exposed areas may need to be given high priorities in order to prevent immediate and long term hazards to building occupants.

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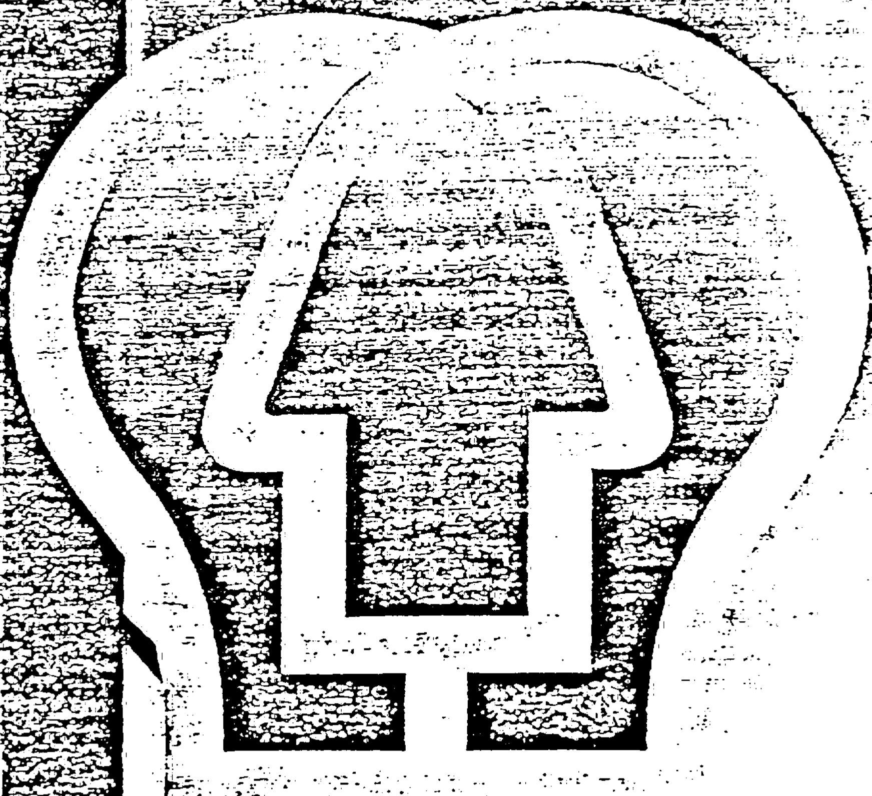

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